Commercial Fruit &
veg. products.

CRUESS

PREFACE TO THE FIRST EDITION

This book has been prepared primarily to serve students in horticulture, food chemistry and horticultural products Therefore the application of the fundamental sciences to the manufacturing and preserving processes concerned is given prominence equal to that of the strictly practical phases. The book is based upon lectures given by the author to students in fruit and vegetable products during the past twenty years and the subject matter is developed from the viewpoint of the instructor rather than from that of the manufacturer.

Nevertheless, it is believed that commercial canners and others engaged in the fruit and vegetable products industries will find most of the information given upon their respective industries of direct value in the operation and control of their plants. In addition to serving as a reference book for the factory manager, superintendent, or chemist, the book will be of value to the foremen and other employees in the organization who desire to increase their technical knowledge of the industry.

In conjunction with the "Laboratory Manual of Fruit and Vegetable Products" by Cruess and Christie, the present book may be used as a text for university and college courses in the subject. The list of references given at the end of each chapter may be used by the instructor in assigning outside reading or by chemists and others who may wish to consult original sources.

Fruit and vegetable products have long been important articles of commerce and for many centuries have formed a large proportion of the diet of man. Many of these products were first prepared in the household on a small scale before their commercial production was undertaken and others, since the beginning of their manufacture, have been prepared on a factory scale.

Some may be termed "primary products," since the fruit and vegetables used are grown principally for the manufacture of the products concerned. The canning of fruits and vegetables, the pickling of cucumbers, and the manufacture of tomato catsup are primary industries. The manufacture of vinegar from waste fruits, of fixed oil from apricot kernels and raisin seeds, and of charcoal from fruit pits or hulls are by-product industries, since only fruit waste is used.

Both primary products and by-products are important in relation to modern fruit and vegetable growing.

In order that this book may not cover too wide a field, attention will be centered principally upon those industries more directly affecting the fruit and vegetable grower rather than the producers of field crops and of livestock.

The intelligent application of scientific methods and principles in the fruit and vegetable products industries has been comparatively recent. Although notable advances have been made in the knowledge of the fundamental scientific principles underlying processes used in these industries, there remains to be done a vast amount of research before the manufacturing processes are placed upon the same high plane of efficiency and applied science as, for example, obtains in the manufacture of beet sugar. The opportunities for investigation by chemists, physicists, bacteriologists, and engineers in the fruit and vegetable products field are almost unlimited.

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W. V. Cruess.

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COMMERCIAL FRUIT
AND
VEGETABLE PRODUCTS

CHAPTER I

MICROORGANISMS IN RELATION TO FRUIT AND VEGETABLE PRODUCTS

The fruit and vegetable products industries depend in most cases upon the control or proper utilization of microorganisms. In the canning of foods, microorganisms capable of causing spoilage are destroyed by heat, and their entrance to the food is prevented by the use of hermetically sealed containers. Properly dried fruits and vegetables do not spoil, because they do not contain sufficient moisture to support the growth of microorganisms. In the manufacture of wine and vinegar the growth of microorganisms is encouraged, and success depends upon their proper development. Molasses, waste fruit juices, potato mash, and other sugary materials are fermented with yeast in making denatured alcohol; alcoholic fermentation by yeast is used also as a preliminary step in the clarification of lemon juice for citric acid manufacture.

In nearly all the industries to be discussed in this book microorganisms are of importance and must be considered in any thorough presentation of the subject.

RELATION OF FUNGI TO OTHER PLANTS

Microscopical plants are of much greater importance in the horticultural industries than are microscopical organisms of the animal kingdom.

Microscopic plants are placed in two large groups: (1) Fungi, and (2) Algae. Fungi differ from Algae in that they contain no chlorophyll, and from most other plants in that they do not possess chlorophyll, vascular bundles, or true roots and do not produce flowers. They are, therefore, much simpler in structure than the higher plants. Their general relation to the higher plants may be seen from the following list of subkingdoms of the vegetable kingdom:

1. Spermatophyta.—Flowering and seed-bearing plants. Includes all fruit trees and most cultivated plants.

2. Pteridophyta.—Vascular cryptogams; possess leaves, stems, true roots, and vascular bundles, but are not true flowering plants. Includes ferns and horsetails, etc.

3. Bryophyta.—Possess leaves and stems but not true roots or vascular bundles and do not produce true flowers; including mosses, liverworts, etc.

4. Thallophyta.—Have no leaves, true roots, or vascular bundles; nonflowering. Under this subkingdom are placed the classes of Fungi and Algae.

Some authors add a fifth subkingdom of Schizophyta, or plants that reproduce by fission; in this group the bacteria and several other types that reproduce by splitting rather than by budding or acrogenous growth are placed. For our purpose, however, the most convenient classification is the one in which the bacteria are placed under a subdivision of the Fungi including two groups, fission Fungi or Schizomycetes, true, or budding, Fungi or Eumycetes, and the "slime molds "or Myxomycetes.

INDUSTRIAL CLASSIFICATION OF MICROORGANISMS

The complete classification and description of the microorganisms of importance and interest to the manufacturer of horticultural products would be beyond the scope of this book. A brief discussion of the more important forms only will be given. The classification on page 2 may be

Classification of Microorganisms of Importance to Horticultural Industries

FUNGI

Fission Fungi

1. Coccaceae (spherical):
   - *a.* Diplococcus, usually in groups of two cells
   - *b.* Tetracoccus, in groups of four cells
   - *c.* Sarcina, in groups of eight cells
   - *d.* Streptococcus, in chains of cells
2. Bacteriaceae (rod forms):
   - *a.* Bacterium (plural bacteria), nonmotile rod
   - *b.* Bacillus (plural bacilli), motile rod
3. Fission yeasts: Schizosaccharomyces

Budding Fungi

Yeasts (no mycelium):

1. True yeasts (form spores)
   - *a. Saccharomyces ellipsoideus* (wine yeast)
   - *b. Saccharomyces cerevisiae* (beer yeast)
   - *c. Saccharomyces malei* (cider yeast)
   - *d. Saccharomyces pastorianus*
   - *e. Saccharomyces anomalus* (*Willia anomala*)
   - *f. Saccharomyces ludwigii*
2. Pseudo yeasts (no spores)
   - *a. Apiculatus* (*Hansenia*)
   - *b.* Mycoderma
   - *c.* Torula

Molds (form mycelium):

1. Penicillium
2. Aspergillus
3. Mucor
4. Botrytus
5. Oïdium
6. Monilia
7. Dematium
8. Cladosporium
9. Alternaria

termed an "industrial classification," or classification for industrial purposes, because it includes only the forms of interest to the student of horticultural products and is not arranged in strict accordance with most botanical classifications. It does, however, serve very satisfactorily as a reference table for the subject under discussion.

MOLDS

Molds are distinguished by the formation of a mycelium, which is a network of filaments or threads. These threads are termed "hyphae" (singular, hypha) and are usually visible to the unaided eye.

Molds differ from each other principally in their methods of producing spores and conidia, but there are also easily recognizable differences in the appearance of the mycelium and in the nature of the chemical changes induced in media suited to their growth. Variations in external and microscopical appearance, however, are not always reliable for identification and classification as the appearance is often affected profoundly by circumstances. Sometimes the mycelial cells form compact masses of rather firm texture, as in mushrooms. Such a mass, which becomes dry and firm with thick hard walls, is called a "sclerotium." Some fungi form a mycelium without cross walls (nonseptate), and the mycelium is termed "nonseptate" or "coenocytic." These molds are also termed Phycomycetes. The other Fungi possess a septate mycelium.

Some molds form yeast-like cells under certain conditions and may even induce feeble alcoholic fermentation, as in some of the Monilia and Mucor molds.

Molds are also grouped as Basidiomycetes which includes mushrooms, puffballs, and bracket fungi; the Ascomycetes, which include many of the septate molds and spore-forming yeasts; and the Fungi Imperfecti, which do not exhibit the complete life cycle of the Ascomycetes. The spores of the Ascomycetes are enclosed in an ascus or sac. The Fungi Imperfecti include most of the Penicillia, certain other molds, and several species of yeasts.

Penicillium.—Of the molds given in the foregoing table those of the Penicillium group are the most common and most troublesome to the manufacturer of fruit and vegetable products. C. C. Thom of the U. S. Department of Agriculture has made an exhaustive study of the Penicillium molds.

In the initial stages of growth, Penicillium is white and cottony in appearance. Later, spores or conidia are formed in enormous numbers and give a powdery appearance to the growth, which is blue, or brown, or pink, according to the color of the conidia and the age of the growth.

P. glaucum or more correctly *P. expansum*, is the best known of the Penicillium molds and the one responsible for very great losses to fresh fruit shippers and fruit products manufacturers. Unfortunately, this

term has been applied to many green forms of Penicillium, a large proportion of which are not *P. glaucum*. Thom makes four main subdivisions of the Penicillia. These are the Monoverticillata, with a single whorl of spore-bearing sterigmata; Biverticillata-symmetrica, with two whorls;

FIG. 1.—Common molds of importance in the horticultural industries: 1, *Oidium;* 2, *Alternaria;* 3, *Penicillium expansum;* 4, *Aspergillus niger;* 5, *Botrytus cinerea;* 6, *Mucor* species from grapes.

the Polyverticillata-symmetrica, with several whorls symmetrically arranged; and the Asymmetric, with whorls asymmetrically arranged.

P. glaucum.—This species is objectionable principally because of its very disagreeable "moldy" odor and flavor. In young cultures the

growth is white and filamentous. The color later turns to blue or green with the formation of spores and in old cultures becomes brown. The spores or conidia are spherical in shape and are formed in great abundance upon upright hyphae or conidiophores. The conidiophores are branched only in the upper portion. The fructifications consist of a complex system of branches, the ultimate fertile cells of which produce chains of conidia by constriction.

The conidia are light and are carried by air currents. They are universally distributed on surfaces and in the air; all fresh fruits and vegetables carry spores of this organism on their surfaces. This mold will grow on practically all food materials exposed to the air, if the conditions of moisture content and freedom from antiseptics permit the growth of any microorganism. It prefers sugar-containing substances such as fruits, fruit juices, jams, etc., but will develop on such unpromising material as moist leather. Any acid material affords a more favorable medium for growth than does an alkaline or neutral medium.

Growth is most abundant at temperatures ranging from 15 to 25°C. but will occur at temperatures near the freezing point, 0°C., and slowly at temperatures of 35 to 37°C.

Other Penicillia.—Other important Penicillia are *P. italicum* and *P. digitatum* (also called *P. olivaceum*), which cause decay of citrus fruits; *P. rocqueforti Thom*, *P. camemberti* used in making rocquefort and camembert cheese; and *P. brevicaule* well known for its ability to form diethylarsene, a substance of garlic-like odor from arsenic compounds. Some Penicillium molds form citric acid but have been displaced by Aspergillus for this purpose industrially, since it is more productive and efficient. Others are used industrially in the manufacture of gluconic acid.

Aspergillus.—The members of this group are recognized by their peculiar method of conidia formation. The conidia are borne upon upright conidiophores which terminate in abrupt enlargements or "knobs." From these enlargements known as "vesicles," spring numerous spike-like projections—the sterigmata—bearing chains of conidia. The general appearance of an Aspergillus mold under the microscope may be seen in Fig. 1. Thom and Church have published a book on the Aspergillus molds in which a key to the various groups and their principal characteristics are given.

A. niger.—This species is almost as common and as well known as *Penicillium glaucum*. Growth at first resembles that of the Penicillium molds, being white and cottony. After conidia are formed in abundance, the growth becomes black in color. Unlike *P. glaucum* it does not produce a moldy flavor or odor. It is noted for its ability to transform sugars into oxalic acid, and under the microscope the acid crystals can often be seen in the mycelium. Under proper conditions it forms citric

acid from various sugars and is now being used industrially on an extensive scale for this purpose (see Smyth and Obold, and Butkewitsch, and also Chap. IV). *A. niger* has been studied by many biochemists, especially in its behavior toward metallic salts, the formation of oxalic acid serving as a measure of its activity. It is found very frequently on fruits and vegetables and often develops on jellies, jams, marmalades, and in insufficiently sterilized fruit juices.

A. glaucus.—This mold causes considerable damage to grains, especially barley, during the malting process. It occurs on jellies, preserves, and other concentrated foods and on hay. It readily forms perithecia, spore sacs, in such abundance that a yellow color is imparted to the culture. It is not utilized industrially.

A. oryzae.—This species is of fundamental importance to the saké industry of Japan. It is grown on soaked rice, which is later dried at room temperature. The dried product, known as *koji*, is a mass of spores and is used to inoculate steamed or soaked rice to be used for saké manufacture. The mold converts the starch of the rice into sugar, which may then be fermented to form rice wine or saké. It can also be used to saccharify the starch of potatoes, etc., for industrial alcohol manufacture. Soybean sauce is made by fermentation of a cooked mixture of soybeans and wheat by *A. oryzae* in the presence of about 15 per cent of salt. Taka-diastase is an important enzyme preparation made by Takamine's process which consists in growing the organism on bran, extracting it with water, and precipitating the enzymes with alcohol.

A. wentii.—This species is used in the Orient, especially in Java, to convert soybeans into various food products. *A. fumigatus* is of interest because it causes a disease in birds of pneumonia-like character and is infectious also to man.

Many other species of Aspergillus have been described, but the foregoing are the most important from an industrial standpoint.

Mucor and Rhizopus.—The molds of the Mucor and Rhizopus groups are widely distributed and several are very common and well known. A general characteristic of these "pin molds" is the possession of a unicellular mycelium in which hyphae are not divided by cross walls or septa. This type of mycelium is designated as "syphonaceous" or coenocytic.

The conidia or spores are borne in spherical sacs known as "sporangia" (singular sporangium), which are usually visible to the unaided eye, and each is carried upon an upright fruiting thread or sporangiophore. At the end of the sporangiophore and inside the sporangium is a swelling known as the "columella."

The Mucor molds occur very frequently upon fresh fruit, especially during shipment. Grapes often develop a hairy, grayish growth of this mold which prevents their sale. Stale breads, if moist, almost invariably

develop a vigorous growth of Mucor and on this account the Mucors are often termed "bread molds."

Most members of this group are capable of converting starch into sugar. In sugary liquids under anaerobic conditions, yeast-like cells are formed which convert the sugar into alcohol and carbon dioxide. Very few molds possess this characteristic. Because of their strong diastatic or starch-hydrolyzing power several of these molds are of great importance industrially. The Mucors are closely related to the Rhizopus molds, which they resemble very closely. On a Petri dish of agar, Rhizopus rapidly covers the plate and climbs the walls, where the rhizoids, or "hold-fasts," attach themselves, as they do also to the lid. The Mucor molds also rapidly cover the agar but do not develop rhizoids. Also in Rhizopus, the columella is hemispherical, whereas in Mucor it is round, pear-shaped, or cylindrical and never hemispherical. Both form zygospores, sexual spores, by the fusion of two hyphae (two portions of mycelium). The zygospore is very large and usually possesses a rough, warty surface. When formed by fusion of hyphae of the same plant, the species is called homothallous; if by fusion of hyphae of two separate plants, it is heterothallous.

M. mucedo.—*M. mucedo* is one of the most common of the Mucors. By incubating fresh horse manure in a moist chamber, it will usually be obtained. It also frequently appears on foodstuffs. The sporangiophore is unbranched and the columella cylindrical.

M. Rouxii.—This is one of the most active of the Mucors in transforming starch to sugar. In solid or gelatinous starchy mixtures it develops as a mold; in liquids, as a yeast. It is used extensively in Japan and China to convert rice starch to sugar for fermentation purposes. Several varieties, of which Amylomyces β is well known, are used in Europe and the United States in the manufacture of denatured alcohol from cereals.

Other Mucors.—A number of Mucor and Rhizopus molds are found in the fermentation industries of Asia, among them being *M. mucedo*, *M. circinelliodes*, *M. racemosus*, *M. javanicus*, *M. plumbeus*, *R. oryzae*, and *R. javanicus*. *R. nigricans* is by far the most common of the members of the Rhizopus group. It is frequently encountered as a spoilage organism on fresh fruits and vegetables, causing considerable loss to shippers of strawberries when it gains entrance into the fruit tissues through abrasions or through the stem cavity. *R. oryzae* is used in converting rice starch to sugar in the preparation of an alcoholic beverage. *R. japonicus* occurs as a contaminant in *koji*, the commercial *A. oryzae* preparation used in saké manufacture.

Sclerotinia.—Sclerotinia molds differ from the groups thus far described in that they are parasites; those previously described being saprophytes. The sclerotinia molds are found frequently on fruits, where

they may cause great damage. An example is the brown rot of apricots.

Botrytus cinerea (*S. fückeliana*) may develop upon grapes during rainy and foggy weather as a short, grayish, hair-like growth. The mycelial threads penetrate the grape skin and feed upon the juice. It does not affect the flavor of the grapes but causes rapid evaporation of the water from the juice, which results in a concentration of the sugar content to such a degree that grapes too sour for wine making become sweet enough for the purpose. The sauterne wines of France owe their quality to this fact.

It may also develop upon grapes during shipment and cause loss.

Under the microscope the spores are seen to occur in grape-like clusters, as shown in Fig. 1.

S. fructigena causes brown rot of various fruits and attacks fruit on the tree (or in boxes) in fruit regions of the eastern United States. It is one of the most widely distributed and destructive of the fungus parasites. *S. cinerea* or *S. laxa* is probably the cause of apricot brown rot in California, a disease which causes serious damage to apricots in the Santa Clara and San Benito valleys. It spoils considerable quantities of apricots and peaches in lug boxes after picking and is therefore of concern to the canner.

Oïdium.—The molds of this group belong to the Fungi Imperfecti, as do also the Monilia molds with which they are sometimes confused. However, the tendency is now to reserve the name of Oïdium for those molds that form free cells by segmentation or disarticulation of the mycelial threads. Often the cells are barrel-shaped in outline and have flattened ends. The cells are called oïdia.

The most common Oïdium is *O. lactis* frequently encountered on foods containing lactic acid such as pickles, sauerkraut, beer wort, ensilage, cheese, and butter.

It forms a pure white, felt-like mycelium on culture media. Under the microscope, mycelial threads as well as the characteristic barrel-shaped oïdia will be found.

It is strongly proteolytic and may cause undesirable changes in dairy products. It is also probably responsible for some spoilage of pickles and sauerkraut, particularly after these products reach the retail distributor.

Monilia.—The genus Monilia includes a number of species of mold-like organisms that under suitable conditions form yeast-like cells. Yeast-like cells also form by budding on the sides or on the ends of the filaments. In sugary liquids, such as fruit juices, these cells reproduce by budding and closely resemble yeasts not only in appearance but also in their ability to induce an alcoholic fermentation. Often long chains or branching chains of the yeast-like cells are formed. The Monilia are usually placed in the

imperfect fungi group although *M. sitophila* has been shown by Shear and Dodge to form perithecia containing ascopores. They have therefore suggested it as a new genus *Neurospora sitophila*.

Some of the monilia form an aerial mycelium while others form only a submerged mycelium; sometimes monilial forms represent a stage in the growth of Sclerotinia, the monilial stage of *S. fructigena* being the destructive stage of brown rot.

M. candida is frequently found on fruits. It forms a pellicle on fruit juice and ferments dextrose, levulose, maltose, and sucrose. *M. nigra* is found on raw cane sugar and owes its name to the fact that old colonies on agar become black in color. *M. fusca* resembles *M. nigra;* both are destructive to raw sugar.

A number of pathogenic yeast-like organisms causing disease in animals and man are termed Monilia, but they do not closely resemble the Monilia encountered on fruits.

Dematium pullulans.—This organism develops as a leathery growth of black color and is commonly known as "tree mold." It occasionally develops in fruit juices, rendering them slimy. It forms yeast-like cells and chains of black cells which can easily be recognized under the microscope. The writer has occasionally recovered it from grapes and apples.

Alternaria is found frequently on fruits, especially on grapes in California that have been left upon the vine until after the fall rains. It appears as a brownish-green growth similar in appearance to Penicillium. Under the microscope the conidia resemble Indian clubs divided by walls, as shown in Fig. 1.

Fusarium.—This organism causes wilt of tomatoes and potatoes and is one of the most destructive of the tomato and potato diseases. It is recognized by its sickle-shaped conidia.

YEASTS

Alcoholic fermentation, upon which the manufacture of industrial alcohol, wine, and vinegar depends, is caused by yeasts. On this account they are of very great importance in these horticultural products industries. They are distinguished from the molds in that they permanently maintain a unicellular growth and do not form a true mycelium. However, it is considered by many microbiologists that yeasts have been derived from molds, since many molds will form yeast cells under suitable conditions, such cells often inducing alcoholic fermentation. The ascospores of some species of yeasts closely resemble those of certain molds. Thus the spores of *Willia anomala* (*Saccharomyces anomalus*) closely resemble those of the mold *Endomyces fibuliger*. Several other yeasts form spores resembling those of certain molds. Copulation precedes ascopore formation in the yeasts of the Schizosaccharomyces group, similar to the copulation process

of certain Ascomycetes. The asci and the ascopores of the two groups are much alike morphologically.

General Classification.—Yeasts are classified in two ways, one based upon morphology and the other upon their use in the industries. Thus we

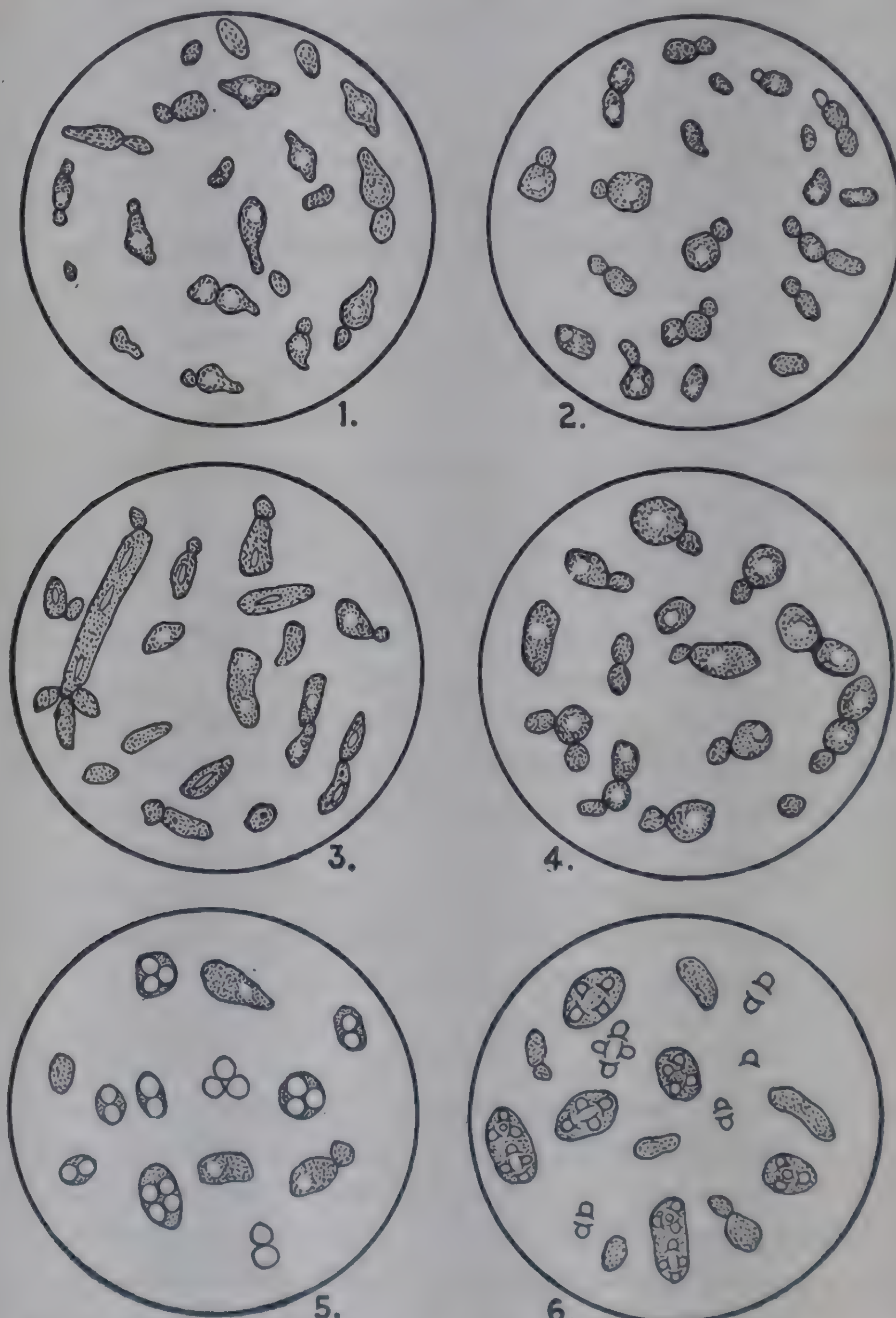

FIG. 2.—Common yeasts of importance in the horticultural industries: 1, *Apiculatus;* 2, *Torula;* 3, *Mycoderma vini;* 4, *Saccharomyces ellipsoideus;* 5, *S. ellipsoideus* with spores: 6, ***Willia anomala*** **(*S. anomalus*) with spores.** (*Original.*)

have "culture yeasts," which are useful in the industries, and the "wild yeasts," or all yeasts not useful in the industries. The distinction is sometimes carried further, and a yeast useful in one industry—*e.g.*, bread-making—would in this industry be termed a culture yeast, while if it

should develop in the fermentation of fruit juice, it might be termed a wild yeast. The second method of classification is based upon morphological and physiological properties and especially upon spore formation. Thus, yeasts which form spores are classed as "true yeasts," and those which do not form spores are "pseudo yeasts." All culture yeasts are also true yeasts but many true yeasts are not culture yeasts, for the reason that many of the spore-forming yeasts are injurious to the quality of products in which they may occur.

In discussing the classification of yeasts we shall consider them under the groups of true yeasts and pseudo yeasts. The Saccharomyces yeasts belong to the tribe Saccharomycetaceae, which in turn belongs to the subfamily Saccharomycoidae. In this subfamily are also included the tribe Endomycopseae, a yeast-like group of molds, and the tribe Nadsonieae. The latter includes three genera. The first is Saccharomycodes, with lemon-shaped cells that form four spores per cell, the spores germinating after copulation. The second is Hanseniaspora, with lemon-shaped cells formed parthenogenetically; spores are round to hat-shaped. The third is Nadsonia with egg- to lemon-shaped cells that form spores after heterogamic copulation of a mother cell and its bud; the spores are round, one per cell.

The tribe of Saccharomycetaceae propagate by budding and form spores parthenogenetically or after isogamic or heterogamic copulation. The following genera and subgenera are included in this tribe:

1. *Saccharomyces.*—Growth form round; oval to long yeast cells; sometimes a pseudo mycelium present. Spore production after isogamic or heterogamic copulation; or are formed parthenogenetically. Spores round, kidney form, or hat-shaped, smooth; one to four per ascus. Dissimilation always oxidative, more or less strong fermentation.

Subgenera: a. Saccharomyces.—Spore production parthenogenetic.

b. Zygosaccharomyces.—Spore production near parthenogenetic or after isogamic or heterogamic copulation.

2. *Torulospora.*—Cells predominantly round; spore formation after copulation trial; spores round, smooth, one to two per ascus. Always actively fermentative.

3. *Pichia.*—Oval to long cells, pseudo mycelium; spore formation isogamic, heterogamic, or parthenogenetic; spores angular or semispherical, one to four per ascus.

Subgenera: a. Pichia.—Parthenogenetic.

b. Zygopichia.—Isogamic or heterogamic or nearly parthenogenetic.

4. *Hansenula.*—Yeast cells oval to long, seldom round, pseudo mycelium; spore production parthenogenetic, spore spherical, or semispherical with a border; two to four per ascus. Surface forms oxidative, quite strongly fermentative.

5. *Debaryomyces.*—Predominantly round cells, sometimes oval; pseudo mycelium sometimes present. Spore formation proceeds after heterogamic or isogamic copulation; spores round, warty, one to two per ascus. Mostly oxidative, but sometimes fermentative.

6. *Schwanniomyces.*—Oval yeast cells; spore production after previous copulation trial; spores round, warty, bordered, 1 or seldom 2 per ascus. Always predominantly fermentative.

The most important group of true yeasts is that of Saccharomyces in which are found cider yeasts, wine yeasts, industrial yeasts, beer yeasts, and bread yeasts.

Size.—Yeasts are microscopic in size, and it is only the very large aggregations of cells that are visible to the naked eye. A cake of compressed yeast contains several billion cells. A cider or wine yeast cell is about $7/1000$ by $5/1000$ mm. in size, or simply 7 by 5μ.

Multiplication.—An active yeast cell in a favorable liquid will increase in 48 hr. to many million cells. Because of this rapid rate of multiplication, yeasts will often displace other microorganisms, particularly molds, in a liquid which is favorable to both, a fact which makes possible the rapid fermentation of fruit juices or other sugary liquids.

Spore Formation.—Under conditions of temperature and moisture supply that are favorable for the process, the true yeasts form endospores. Abundant moisture, very little food, and a temperature range of 10 to 30°F. favor spore formation. Figure 2 illustrates the microscopic appearance of spores in a typical wine or cider yeast and in *Willia anomala*. Spores have a definite function in the life cycle of the yeast since they are very resistant to adverse conditions and probably enable the yeast to pass through the winter.

Saccharomyces.—Only those yeasts of frequent occurrence and importance in the horticultural industries will be discussed further.

S. ellipsoideus (Wine Yeast).—Although classed as a wine yeast, this organism is used in the fermentation of all fruit juices for wine, cider, vinegar, and alcohol manufacture. The species contains a great number of varieties, many of which have been used in pure culture in the fermentation industries.

The microscopical appearance of vigorous cells is shown in Fig. 2, from an examination of which it will be seen that the shape of the cells varies from spherical to almost sausage-shaped. The usual size of the cells is about 8 by 7μ.

The spores of this yeast are formed in abundance on gypsum blocks. Two or three spherical spores per cell are the numbers usually formed; one or four less commonly (see Fig. 2).

Most of the yeasts of this species form high amounts of alcohol in liquids containing an excess of fermentable sugar, the formation of 16 per cent alcohol by volume not being uncommon.

A vinous or wine-like flavor is produced in liquids fermented by *S. ellipsoideus.*

In liquids containing sugar the first evidence of growth is a slight haziness in the liquid and the formation of a white sediment. As growth proceeds, gas is formed, rises through the liquid, and during active fermentation forms a foam of froth at the surface. The gas carries the cells through the liquid, causing it to become cloudy. At the same time a strong odor of fermentation develops. Near the end of fermentation the sweet taste of the sugar disappears and is replaced by a sharp and alcoholic flavor caused by the alcohol and carbonic acid gas formed from the sugar. After fermentation is complete the yeast cells settle to the bottom of the container to form a compact white or grayish-white sediment. At temperatures of 25 to 33°C., 77 to 90°F.—the optimum temperature range for *S. ellipsoideus*—most fruit juices will become completely fermented in less than 3 weeks. This rapidity of fermentation makes this yeast of great value in the manufacture of wine, cider, vinegar, and alcohol from fruits.

Grapes and other fruits carry upon their surfaces and in cracks cells of *S. ellipsoideus*, but usually these are greatly outnumbered by wild yeasts, as experiments have demonstrated. It is therefore very desirable, and profitable as well, to augment the numbers of *S. ellipsoideus* cells by the addition of a pure culture of this yeast to fruit juices to be made into wine, vinegar, or other fermented products.

S. cerevisiae (Beer Yeast).—This species is known commonly as beer yeast, but most distillery yeasts and compressed yeasts also are races of *S. cerevisiae.* Just as the *S. ellipsoideus* yeast is the most important fruit yeast, the *S. cerevisiae* yeast is the most important cereal yeast. Because it is used in breadmaking, it is probably the most important yeast used by man.

Under the microscope most varieties of this yeast appear either spherical or egg-shaped.

S. cerevisiae cells are usually larger than the average *S. ellipsoideus* cells, the average being about 8 by 10μ or 9 by 9μ.

The spore formation curves of *S. cerevisiae* (obtained by plotting the time necessary for spores to form, against temperature) have been studied very thoroughly by European investigators, especially by Hansen, the founder of the scientific study of fermentation. As a result of this and other lines of study of this species, many varieties or "races" have been discovered and described. These yeasts are better adapted to the fermentation of cereal products, molasses, and potato mash than of fruit juices.

Most beer yeasts form less than 10 per cent alcohol, but some of the distillery yeasts form 15 to 16 per cent alcohol by volume. Most compressed yeasts used for breadmaking belong to the distillery-yeast type

rather than to the brewery-yeast group. They impart a beer-like odor and flavor to liquids fermented by them. The compressed yeast easily adapts itself to the fermentation of fruit juices of low sugar content, such as cider, and can therefore be used successfully in fermenting apple juice to be made into vinegar, although yeasts of the *S. ellipsoideus* group are much better suited to the fermentation of all fruit juices, particularly those intended for use as wine or cider.

S. saké (Closely Related to *S. ellipsoideus*).—It is used in the Orient for the fermentation of rice wort for saké and brandy manufacture. The starch of the rice is converted to sugar by *Mucor rouxii* or *Aspergillus oryzae*, and *S. saké* ferments the sugar thus formed to alcohol and carbon dioxide. Both fermentations proceed simultaneously. Because of this gradual furnishing of sugar to the yeast by the mold, very high amounts of alcohol are formed. A yield as high as 22 per cent has been recorded. The mixture of mold and yeast used as a starter is known as *koji.*

S. malei (apple cider yeast) is often found on fruits. It differs from *S. ellipsoideus* in having a lower alcohol-forming power and in producing a slower fermentation. Because of its slower rate of fermentation and lower alcohol-forming power, it is useful in the manufacture of sparkling hard cider. The cells of *S. malei* are usually larger than those of *S. ellipsoideus.*

S. anomalus (*Willia anomala*).—Recently this yeast has been placed in a separate genus, that of *Willia*, because of its peculiar spores. It is most commonly known, however, by the name of *S. anomalus*. It is recognized by its peculiar hat-shaped spores illustrated in Fig. 2.

This yeast develops as a heavy white film on the surface of sugary liquids. It forms small amounts of alcohol (less than 8 per cent) but develops relatively large amounts of aromatic esters, especially ethyl acetate. It may seriously interfere with the normal fermentation of fruit juices and has in the past been very troublesome in distilleries. It has been used in Japan in the aging of saké.

S. pyriformis is found in ginger beer and resembles *S. ellipsoideus* but is less energetic in its fermentation than the latter. It is of considerable use in making homemade ginger ale.

S. pastorianus is a sausage-shaped, spore-forming yeast occasionally occurring in fermenting fruit juices. It produces a bitter flavor and cloudiness.

Other Genera of True Yeasts.—Most of the other genera of Saccharomycetaceae are of little importance industrially. Pichia is a film-forming yeast often confused with the pseudo yeast, Mycoderma. Pichia forms peculiar angular or semispherical spores. It forms none to very little alcohol. It has been found in souring figs and on pickle brine in California and has been recovered by European investigators from various sources. There are several species.

Zygosaccharomyces is a genus containing rather a large number of species. Asci result from copulation of two cells, the cells being so joined by a tube that together with the tube they have the appearance of a dumb-bell. Several species have been isolated from food products of the East—such as so-called Chinese yeast used in fermenting sugary liquids for distillation for brandy—from soybean sauce, and from raw sugar. One, *Z. priorianus*, was isolated from beer; another, *Z. nadsonii*, from orange syrup. The Zygosaccharomyces are active fermenters of sugary liquids.

Saccharomycodes ludwigii, is a large yeast of variable form frequently found in apple juice in California. Many of the cells are lemon-shaped but much larger than those of Apiculatus which also forms lemon-shaped cells. Fermentation is feeble. Usually four spores are formed per asc.

Other genera have been described from fruits, but for the purpose of this book, they may be omitted. Those interested in further information are referred to Guillermond and Tanner.

PSEUDO YEASTS

The yeasts of this group do not form spores, although most of them are capable of carrying on a feeble alcohol fermentation. Practically all of them are undesirable in the fermentation industries. Several, such as Apiculatus and certain Torula yeasts, are capable of completely spoiling fruit juices during fermentation of juices for conversion to wine or hard cider.

Torula.—These yeasts grow as bottom yeasts and do not form spores. The typical form is spherical but may vary from spherical to elongated. No spores are formed. The Torula group is a "catchall," embracing yeasts of widely different properties, which have in common only the properties of bottom growth and lack of spore formation. They are not useful industrially but may be very troublesome during the alcoholic fermentation of fruit juices and other liquids. A pink Torula yeast is very common, being frequently encountered as a contamination upon agar plates. There are also species that form black, and others that form brown, pigments.

Most of the Torulae contain a droplet of oil that gives them a characteristic appearance. They are very widespread, occurring in soil, on fruits, and other food products; and several species are the cause of serious diseases in man and animals.

Several attempts have been made to classify the Torulae into definite subgroups. Will in 1916 placed them in a family that he called Torulaceae and divided them into three genera. Eutorula forms typical fat droplets; Torula does not form these droplets; and Mycotorula is characterized by formation of a pseudo mycelium.

Ceferri and Redaelli placed the Torulae in the family Torulopsidaceae and in the subfamily Torulopsidae. This subfamily was divided into Asporomyces, a genus with a trace of sexuality, and four nonsporulating genera. The latter are: Eutorulopsis, which forms fat globules; Torulopsis, which forms no fat globules in young cells; Kloeckeria, which has lemon-shaped cells and corresponds to Pseudosaccharomyces or to Apiculatus; and Pityrosporum, which resembles Kloeckeria but does not usually form apiculate cells.

Harrison made three groups based on color formation, *viz.*, Rhodotorula, with red pigment; Chromotorula with pigments other than red; and Torula forming no color. He also places those that form a pseudo mycelium in the genus Mycotorula. He subdivides the various genera into nine groups according to their action on various sugars.

Guillermond's classification is very useful. He places them in the family Non-saccharomycetaceae. All pathogenic nonsporeformers are placed in the genus Cryptococcus. Lemon-shaped yeasts that do not form spores are placed in the genus Pseudosaccharomyces. His genus Mycoderma forms thin, dry films and Medusomyces forms thick gelatinous films. All other nonsporeforming yeasts are placed in the genus Torula.

Many Torulae have been described by Hansen, Lindner, Kloecker, Will, Harrison, and others. Only a few will be described here. For a more complete discussion of this group the reader is referred to Guillermond and Tanner or to Harrison.

Owing to their frequent appearance on agar plates in the laboratory the red Torulae are of particular interest. Of these *T. Pulcherrima* is one of the best known. It forms cream-colored to maroon-colored growths on solid media. Traces of iron salts in the medium intensify the color. It ferments dextrose, levulose, and d-mannose. It is not used industrially. According to Guillermond a number of red Torulae have been described under the name *Cryptococcus glutinis* or *T. glutinis.*

T. amara produces a bitter taste in cheese and milk. *T. kephir* is interesting because of its ability to ferment lactose, a property possessed by very few yeasts. *T. ellipsoidea* is associated with *T. kephir* in kefir, a fermented milk beverage. It also ferments lactose. Its cells are *elliptical. T. lactis,* another yeast isolated from milk, ferments lactose readily.

T. communis grows on raw cane sugar, causing considerable decomposition. It grows readily in all concentrations of sugar syrups.

Many Torulae are resistant to salt and have been found in strong pickle brines, in sauerkraut, and on salt codfish.

T. thermantitonum is of interest as it will grow at temperatures up to 84°C.

Torulae are frequently found in beer where they may induce secondary fermentations—in some cases beneficial, in others undesirable. Cruess found that Torulae also usually appear in the spontaneous fermentation of grape musts. Pearce and Barker have described a number of Torulae occurring in fermented apple cider in England.

Recently the writer isolated from muscat grapes and wine a Torula that occurred during the 1934 season in muscat must during its fermentation for sweet wine.

Apiculatus yeast (*Pseudosaccharomyces*, "*S. apiculatus*").—This yeast was at one time termed *Saccharomyces apiculatus* but is now usually designated as nonsporulating Hansenia or Pseudosaccharomyces in most references on yeasts. It forms small lemon-shaped to *ellipsoidal* cells. According to several European investigators, particularly Kloecker, Lindner, and Guillermond, the group of apiculate yeasts consists of several distinct species, some of which can be made to form spores and others of which refuse to sporulate. Those that form spores are by some microbiologists termed Hanseniaspora or *S. apiculatus* and those that do not form spores Hansenia. One form, *viz.*, *H. valbyensis*, forms two hat-shaped spores per cell.

In microscopical appearance some of the cells of the apiculate yeasts are lemon-shaped, although many of the cells are ellipsoidal, sausage-shaped, or even spherical. The cells are very much smaller than those of most yeasts. Because of its shape, irregularity of form, and its small size, it is readily recognized and need not be confused with *Saccharomycodes ludwigii*, which it resembles in shape but which is much larger than apiculatus. Apiculatus is normally about 3 by 5μ in size.

These yeasts are widely distributed on fruits, cereals, and other foods and are nearly always present during the first stages of the spontaneous alcoholic fermentation of fruit juices, this stage often being termed the "apiculatus stage" of fermentation. As fermentation progresses apiculatus is killed by the alcohol formed by *S. ellipsoideus*. The apiculate yeasts form only small amounts of alcohol, from 0 to 6 per cent. Those with which the writer has worked formed 2½ to 4 per cent alcohol by volume in grape juice.

The presence of this yeast during alcoholic fermentation is very undesirable, but it can be controlled and eliminated by the use of pure cultures of selected yeasts as described in Chap. XXIV or by addition of small amounts of sulfur dioxide.

Mycoderma ("Wine flowers").—In this group are placed many species of film-forming yeasts that do not form spores. Some of them cause alcoholic fermentation; others do not. They are further characterized by great oxidative power, being capable of oxidizing the naturally occurring organic acids—such as lactic, tartaric, and malic—and the sugars to

carbon dioxide and water. The *Mycoderma yeasts* are frequently given the name "wine flowers." Some microbiologists place the Mycoderma yeasts in the Torula group. They have been confused by some with *S. sheresensis*, a film-forming true yeast of Spain.

It is very common on pickle brines and on cider vinegar stock, *i.e.*, fermented apple juice intended for conversion to vinegar. With other film yeasts it may cause softening of olives and pickles in brine, by reducing the acidity and hydrogen-ion concentration sufficiently to permit growth of putrefactive and other spoilage bacteria.

The cells are variable in shape, although in most species long, sausage-shaped cells predominate. The cells are unusually transparent and tend to develop in groups or as a pseudo mycelium.

M. cerevisiae was described by Hansen in 1888 from beer and *M. vini* by Wortmann and Winogradsky from wine. It has been customary for microbiologists to designate many of the nonsporulating film yeasts from wine as *M. vini* and from beer as *M. cerevisiae*, although in all probability a number of separate and distinct species are involved.

At least twenty different Mycoderma species have been described (Guillermond) from such varied sources as fruits, wine, beer, saké, and milk. Joslyn and Cruess have reported upon a number of film yeasts isolated from several sources in California. Most of these were extremely resistant to salt and exhibited great oxidative activity.

In Spain a film yeast, *Saccharomyces sheresensis*, is utilized to some extent in the aging of Sherry.

Mycoderma is readily distinguished microscopically from vinegar bacteria by the appearance of the film. It develops first as a thin, chalky-white, easily broken film and later as a grayish-white, heavily wrinkled, crumbly membrane. Vinegar bacteria on the other hand, form a tough, leathery, semitransparent film or no film at all. Most of the Mycoderma yeasts impart an esterial odor to wine, whereas vinegar bacteria usually impart merely an acetic acid odor.

FISSION FUNGI

For our purpose the terms fission fungi and bacteria are practically synonymous, if the word bacteria is used in its broad sense to include true bacteria, bacilli, cocci, spirillae, etc. The fission yeasts are included under fission fungi, but are perhaps more appropriately placed with the budding yeasts.

Bacteriaceae.—Bacteria.

Bacteria are often considered to be nonmotile rods and to not possess flagella (organs of locomotion). Some of the most important forms, from our standpoint, follow. The classifications are based

upon several factors, including morphology, physiological characteristics, and origin.

Vinegar Bacteria (Acetobacter) includes several distinct forms, such as *Bacterium aceti*, *B. xylinum*, *B. Kützingianum*, *B. Pasteurianum*, etc., all characterized by their ability to convert ethyl alcohol, C_2H_5OH, into acetic acid, CH_3CO_2H, by oxidation. "Vinegar mother" is an agglomeration of these bacteria and is one of the usual manifestations of this organism in fermented fruit juices.

Vinegar bacteria develop normally after alcoholic fermentation is complete. They should not be permitted to develop in vinegar manufacture until the yeast has completed its work, because the bacteria retard and even completely inhibit yeast growth with the result that unfermented sugar will remain in the vinegar. The bacteria do not, to any appreciable extent, convert sugar directly into acetic acid, yeast fermentation must precede that of the bacteria.

The bacteria may be present as a slimy, tough, almost transparent film or layer on the surface of the liquid or may be distributed throughout the liquid as individual cells or small groups of cells which give a cloudy appearance to the liquid.

The cells are very small, the usual size being 1 by $\frac{1}{2}\mu$. Their general microscopical appearance may be seen from Fig. 3.

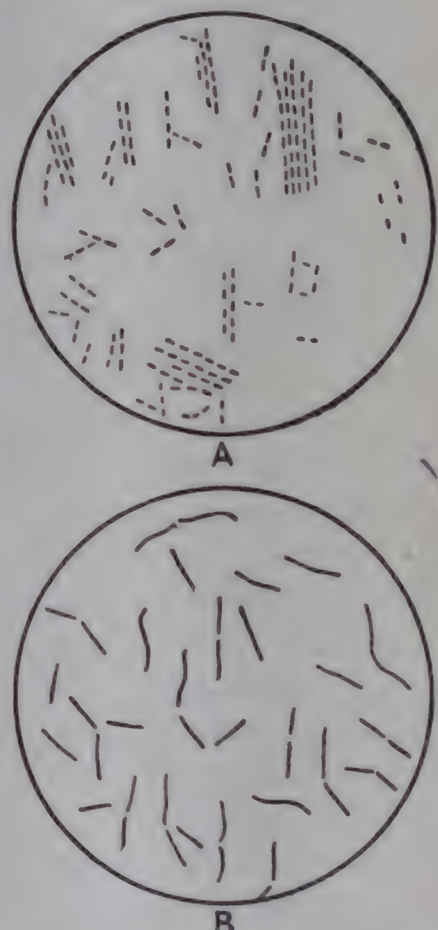

FIG. 3.—*A*, Acetic acid bacteria; *B*, Lactic acid bacteria from pickle stock. Also found in fermented apple juice and wine.

Lactic Acid Bacteria (Lactobacilli).—Lactic acid is produced by a number of different forms of bacteria and bacilli. In general, those occurring in milk are motile (bacillus forms), while those occurring in vegetable products are more frequently nonmotile (bacterium forms), although both groups are commonly termed lactobacilli.

Different strains of lactic acid bacteria vary greatly in their properties. Some can withstand a temperature of 60°C. and still remain active; others are sensitive to temperature and cease formation of acid above 37°C. The types of most importance in the cereal products industries are most active at about 50°C., a temperature at which most other microorganisms cease to function. Thus by merely maintaining the material at 50°C., a nearly pure lactic acid fermentation is obtained. This is done in "souring

the mash" for making compressed yeast, beer, and denatured alcohol, where it is necessary that the sugary liquid be acid in reaction in order to promote the growth and activity of yeast and to check the growth and activity of undesirable organisms. Where lactic acid is to be made commercially from cereals, the same method of temperature control is used. The lactic acid bacteria of sauerkraut and pickles are most active at about 30 to 33°C.

Lactic acid fermentations are used in preserving vegetables by fermentation, in the preservation of ensilage, and in the manufacture of many milk products. The spoiling of such different products as wine and canned vegetables is often due to lactic acid bacteria. A few spore-bearing organisms capable of forming lactic acid sometimes survive sterilizing temperatures, or leaky cans may admit less resistant forms after sterilizing. Thermophilic bacteria are usually lactic acid formers. These are extremely resistant to high temperatures and cause serious losses in the corn canning industry.

The "Tourne bacterium" occurs as a wine and cider disease and is perhaps the most serious bacterial disease of fermented fruit juices. Its growth in fermented liquids is recognized by a peculiar "mousy" odor and flavor and a "silky" cloudiness that increases as the disease progresses. It is a facultative anaerobic and grows after alcoholic fermentation. It is controlled by proper methods of fermentation and pasteurization of the liquids affected. It is very common in vinegar factories and wineries and causes great damage to both quality and yield (see Fig. 3). More will be said of it in the chapter on wine making. A number of other lactobacilli occur in wine (see Chap. XXX).

Bacillus.—The bacilli are rod-shaped and motile. A large number of varieties have been described. Most of these are of little interest to the agricultural products industries. They vary in size from those that can barely be seen with the highest powered microscopes to forms that are 10 to 15μ in length. Some of the more important forms of interest to the horticultural industries are the following:

Bacillus lactis acidi.—This is a short-rod bacillus causing the souring of milk. A related form is *B. bulgaricus*, used in the manufacture of Fermilac and similar sour-milk drinks. *B. lactis* is very active also in the ripening of cheese and in the souring of milk for cheese making. It probably seldom occurs in vegetables preserved by fermentation.

B. butyricus.—This is an anaerobic, spore-bearing bacillus used in the manufacture of butyric acid. It occurs in cheese making, in rancid butter, in ensilage, and in some spoiled canned vegetables. It produces the characteristic disagreeable odor in beet silage and is involved in some forms of olive spoilage.

B. coli Group.—*B. coli* or *Escherichia coli* includes a group of related organisms. They are common inhabitants of the intestines of all warm-blooded animals. Their presence in water is an indication of fecal contamination. A related group is that of *B. aerogenes* (Aerobacter). Both *B. coli* and *B. aerogenes* are involved in the spoilage of certain nonacid food products, particularly olives. *B. coli* is a small, motile, Gram-negative rod.

B. botulinus (*Cl. botulinum*).—This organism is a spore-bearing anaerobe of importance in the spoilage of canned foods. It is a widely distributed and fairly common soil organism. It is heat resistant and develops in improperly sterilized canned foods, occasionally with formation of an extremely virulent toxin (for further details see Chap. XIV).

B. amylobacter Group.—This is a group of anaerobic spore-forming bacilli, some of which are utilized industrially for the production of butyl alcohol, acetone, and butyric acid. They are usually abundant in the soil and on the surface of cereals. Some of the members of this group form butyric acid and acetic acid and others form butyl alcohol and acetone. Carbon dioxide is also formed (for further details see Smyth and Obold).

Other Bacilli.—Another spore-bearing bacillus of importance to the agricultural industries is *B. mesentericus*, the organism which sometimes causes the spoiling of pickles. It is spore-bearing, is of frequent occurrence, and is exceedingly resistant to heat. Many other long-rod spore-bearing bacilli from spoiled foods have been described. Most of them resemble *B. subtilis* and *B. mesentericus* in appearance, etc. *B. sporogenes* is an anaerobe closely resembling *B. botulinus* culturally.

Coccaceae.—The cocci forms are spherical. They are classified largely upon the method of grouping of the individual cells. Numerous species exist. Only a few are of importance in food preservation.

Diplococcus.—This form normally occurs in pairs of cells. Sometimes in spoiled vegetable products.

Streptococcus.—Occurs in long chains of cells.

Tetracoccus.—Occurs in groups of four cells. May be found in fermented fruit juices, causing cloudiness and disagreeable flavors.

Sarcina.—Occurs in "packages" of eight cells each and is found in fermented fruit juices and beer.

Staphylococcus.—The cells of this group of organisms are grouped in large aggregates. Not of much importance in the industries.

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See also references on spoilage organisms at the end of Chap. XIV.

CHAPTER II

GENERAL PRINCIPLES AND METHODS

A brief discussion of the more important principles and processes underlying the manufacture and preservation of fruit and vegetable products should precede the description of methods of applying these principles industrially.

TEMPORARY PRESERVATION

Some of the most important of the food industries are based upon methods of temporary preservation. The method to be chosen will vary with the product to be held temporarily with other factors.

Asepsis.—The inception of spoiling of a food product depends largely upon the numbers of microorganisms present. In the handling of fruit for the manufacture of various fruit products, care in picking, placing in boxes, and in transportation will greatly increase the keeping qualities of the fruit and will usually result in a finished product of superior quality. Dirty lug boxes and rough handling infect and bruise the fruit so that microorganisms are greatly increased in numbers and conditions are made favorable for their growth.

Washing dusty fruit and vegetables before they are used in the manufacture of certain products is often advisable and reduces the number of microorganisms.

Certified milk is made under conditions that tend to exclude most microorganisms from the milk. Its production is a good example of industrial asepsis.

The principle of asepsis is carried to a much higher degree in the manufacture of serums, vaccines, and antitoxins. In these cases the absolute exclusion of microorganisms is sometimes accomplished.

Low Temperatures.—Microorganisms are not killed by low temperatures but their multiplication and activities are inhibited. Low temperatures also retard chemical changes.

Enormous quantities of eggs, meats, fruits, and vegetables are held in cold storage so that they may be made available for a larger proportion of the year. In all cases the principle involved is the same, *viz.*, the temporary inhibition, by low temperatures, of microbiological and chemical action responsible for decomposition.

Exclusion of Moisture.—Moisture is necessary for the development of microorganisms, and the actual growth of mold and other organisms on or

in food products takes place in the juice of the product. If the concentration of dissolved solids in this juice or sap exceeds 70 per cent, *i.e.*, if the osmotic pressure exerted by the solution is equal to or greater than that exerted by a 70 per cent sugar solution, the product will usually keep. If moisture collects on the surface of the dried or other product, it forms a solution lower in dissolved solids than is necessary to prevent growth. It is in this dilute solution that growth often takes place.

Chemical changes in flour, cereals, dehydrated vegetables, oils, etc., are favored by the presence of moisture; hence these products should be stored in a dry atmosphere.

Mild Antiseptics.—Preservatives such as sugar, salt, sodium benzoate, etc., when used in small quantities, exert only a temporary effect upon the microorganisms of spoilage. Cider often is treated with small amounts of sodium benzoate to preserve it temporarily. Vinegar and spices in catsup will prevent spoilage for a time, usually for several weeks after the bottle is opened.

Pasteurization.—When a product is subjected to a temperature which kills a great many, but not all, of the organisms present, the process is spoken of as "pasteurization."

The heating not only kills many organisms but also greatly weakens and delays the development of those not killed, which is an important factor in the keeping of pasteurized products.

The term pasteurization is often applied to the sterilization of fruit juices.. In this case, however, it is very probable that all organisms capable of growing in the liquid are destroyed by the heat, and hence preservation is usually permanent.

Exclusion of Air.—The exclusion of air will often prolong the keeping qualities of fruit products. For example, olive oil becomes rancid on exposure to air but will keep several years if air is effectively excluded. Most fermented products, such as wine, fermented vegetables, and green olive pickles, must be sealed in airtight containers to prevent the growth of aerobic organisms which would spoil them.

PERMANENT PREVENTION OF SPOILING

The permanent preservation of food may be accomplished in several ways, most of which depend upon methods of completely eliminating or preventing the activity of microorganisms capable of destroying the product. The method to be adopted will depend upon the character of the material to be preserved and upon other factors.

Sterilization by Heat.—Sterilization by heat means the complete destruction by heat of all forms of life in the product sterilized. In order that sterilized products shall not spoil, they must be sealed in such a manner that all live microorganisms are excluded.

The temperature necessary to sterilize different products varies. The products that are difficult to sterilize are low in acid, often high in protein and contain spore-bearing bacteria. The acidity of fruits, tomatoes, and rhubarb greatly lowers the death or sterilizing temperatures of the organisms occurring on these products, which explains why acid fruits are easily sterilized, even if spore-bearing organisms are present.

The effect of hydrogen-ion concentration (acidity) is more fully discussed in Chap. X.

Sterilization below 100°C. (212°F.).—Fruit juices are always sterilized commercially at temperatures ranging from 65 to 85°C. Higher temperatures injure the flavor.

One Heating at 100°C. (212°F.).—Fruits are easily sterilized at 212°F. and heating at this temperature is usually for the purpose of cooking the fruit rather than for sterilizing it.

Vegetables, except those of high acidity, when sterilized by one heating, must be heated at 100°C. (212°F.) for 3 to 10 hr. to be certain that all spores are killed.

As a general rule, the one-period sterilization of meats and vegetables at 100°C. (212°F.) is unsafe because of danger of survival of spores of *Bacillus botulinus*.

Intermittent Sterilization at 100°C.—The action of heat is rendered more effective if the time of sterilization is divided into three periods, three sterilizations of 1 hr. each at 100°C. being much more effective than a single sterilization at 100°C. The sterilizations are generally separated by periods of 24 hr. This method is much safer than the one-heating method at 100°C. for vegetables of low acidity. However, it has been proved that this method does not destroy the spores of *B. botulinus* in nonacid foods.

Effect of Acidification.—Vegetables and meats acidified with lemon juice or vinegar are easily sterilized. This principle is made use of in the so-called "lemon juice" method first advocated in *Circular* 158, of the *University of California Agricultural Experiment Station*. In this method a small amount of lemon juice, vinegar, citric acid, or other harmless acid is added to the brine in which the vegetables are canned.

Pressure Sterilization.—The boiling point of water is raised if the water and steam are enclosed in a strong retort (autoclave). A temperature of 116.6°C. (250°F.) or above may be easily attained, and at these high temperatures the spores of the heat-resistant bacteria are quickly killed.

Permanent Preservation by Antiseptics.—Foods may be preserved permanently by the addition of antiseptics in sufficient concentration to prevent the growth of microorganisms. Some antiseptics, such as sugar, salt, and vinegar, are harmless and may be used without reference to the pure food laws. Many chemical preservatives, such as salicylic acid,

formaldehyde, boric acid, etc., are harmful to health, if used in sufficient quantity to preserve the food product permanently and are prohibited by law.

Sugar used in concentrations of 70 per cent or over will permanently preserve most foods, such as fruit jellies, preserves, etc. It acts by osmosis and not as a true microorganism poison.

Salt acts both by osmosis and as a microorganism poison; hence for this reason it is much more effective than sugar. About 15 per cent salt is sufficient to preserve most products. *Acetic acid* of vinegar acts as a microorganism poison and is much more active in this regard than salt. About 1 per cent of acetic acid will prevent the spoiling of most products.

Chemical preservatives are still more active. Two-tenths per cent of sodium benzoate will prevent the spoiling of most acid food products. The amount required varies with the pH value. Thus, Richert, Irish, and the writer found that, below pH 4.5, 0.2 per cent preserved food products and at neutrality, pH 7.0, 1 per cent was insufficient. Sulfurous acid may often act as a permanent preservative for fruit products when used at a concentration in excess of 0.2 per cent. Benzoic acid and sulfurous acid are allowed by law if declared on the label. Other chemical preservatives in foods are prohibited in the United States.

Drying.—Preservation by drying depends upon reducing the moisture content to the point at which the concentration of the dissolved solids in the product is so high, 70 per cent or above, that osmotic pressure will prevent the growth of microorganisms.

The amount of drying necessary will depend largely upon the composition of the food. Thus fruits very rich in sugar are not usually dried to as low a moisture content as fruits low in sugar.

The various methods of accomplishing drying will be fully discussed in a later chapter.

Preservation by Fermentation.—Microorganisms may be used for the preservation of foods as well as for their decomposition. *Fermentation* may be defined as the decomposition of carbohydrates by microorganisms or enzymes as contrasted with *putrefaction*, which may be defined as the bacterial decomposition of proteins.

Alcoholic Fermentation.—Alcoholic fermentation by yeast results in the decomposition of the simple hexose sugars into alcohol and carbon dioxide, as indicated by the following reaction:

$$C_6H_{12}O_6 + \text{yeast} = 2C_2H_5OH + 2CO_2$$

The keeping quality of alcoholic beverages depends upon the presence of the alcohol. Usually air must be excluded from products fermented by yeast in order to prevent the activities of aerobic organisms, such as vinegar bacteria, molds, and mycoderma yeasts.

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Acetic Fermentation.—Vinegar fermentation follows normal alcoholic fermentation and is brought about by vinegar bacteria. The keeping quality of vinegar is entirely due to the antiseptic action of the acetic acid. The most important use for the preservative action of the acetic acid is for the preservation of various food products, such as pickles, relishes, etc. The reaction involved in acetic fermentation is:

$$C_2H_5OH + O_2 = CH_3CO_2H + H_2O$$

Lactic Fermentation.—Lactic acid fermentation is used very extensively in the preservation of sauerkraut, dill pickles, fermented string beans, etc. Materials that have undergone lactic acid fermentation must be kept sealed from the air to prevent the growth of acid-destroying aerobes; hence the necessity of making silos airtight and of sealing sauerkraut and similar lactic acid fermented products from the air. Lactic acid fermentation is a decomposition of the hexose sugar molecule as indicated by the following reaction:

$$\underset{\text{Dextrose}}{C_6H_{12}O_6} = \underset{\text{Lactic acid}}{2C_3H_6O_3}$$

The usual yield of lactic acid is about 90 per cent of the theoretical.

Exclusion of Air.—Some food products are spoiled by the simple oxidizing action of the oxygen of the air; others by the action of microorganisms that require air for their development. Fermented products must be sealed from the air in some manner if the action of mold, vinegar bacteria, Mycoderma yeasts, and other organisms is to be prevented. This is especially true of fermented vegetables.

MANUFACTURING PROCESSES

Many of the industrial processes by which fruits and vegetables are converted into more valuable products are not those of simple food preservation but are highly developed manufacturing processes. The principles of the more important of these are outlined below.

Separation of Valuable Materials from Less Valuable Materials.—A large number of processes are based upon this principle. Of these the more important are:

Crushing and Pressing.—Crushing and pressing of fruits, sorghum, and sugar cane result in the separation of the valuable juices and saps from the less valuable pulp and fiber.

Filtration.—Many liquids, such as fruit juices, wines, vinegars, vegetable oils, etc., contain solid material that must be removed by filtration. In most cases the liquid is the valuable portion but in some instances the main value lies in the solid residue. Thus, in the manufacture of citric acid the calcium citrate is a valuable solid and is separated from the lemon juice by filtration.

The simplest filter is the jelly bag of the type used by the housewife in preparing fruit juices for jelly. Paper filters are used for the filtration of olive oil in many factories. Filter presses employing cloth or other filtering medium, wood pulp filters, and filters employing asbestos fiber are used. These will be described in Chap. XV. Often a filter aid such as diatomaceous earth is added to the liquid to be filtered.

Flotation.—Materials that are mixed and of different specific gravities may be separated by placing them in a liquid in which one will sink and the other will float. After the pits have been crushed, apricot hulls and kernels are separated in this way. In a similar manner frozen oranges are separated from the sound fruit in running water. Overmature peas may be separated from green peas for canning by use of brines.

Leaching.—Sugar, alcohol, and other soluble materials may be separated from fruit pomace, etc., by treatment with water, and oils may be recovered from oil-bearing material, such as olive pomace, by the use of an oil solvent.

Diffusion.—This is a method similar to the preceding and is used mostly in beet sugar manufacture. The sliced beets are surrounded by warm water in a series of tanks known as a "diffusion battery." The sugar diffuses through the cell walls of the sliced beets into the surrounding water, and this solution is drawn off and concentrated. The same principle may be applied to other vegetables and fruits. It depends upon osmosis, *i.e.*, the tendency of liquids outside and inside the cell to come to the same concentration.

Distillation.—Volatile compounds can be separated from less volatile ones by distillation. Alcohol is separated from water and from other less valuable materials, and in this manner essential oils are recovered from the flowers, herbs, or fruits in which they occur.

Types of stills vary greatly in size and design. Most commercial stills for alcohol contain rectifying columns, through which the vapors pass; the columns are maintained at such temperature that the constituents are condensed at different points and separated.

All stills, not only vaporize one or more constituents, but condense the vapors to liquids again, *i.e.*, they consist at least of a still in which the materials are vaporized and a condenser in which the vapors are condensed. By the simple distillation of a fermented fruit juice, it is possible to obtain, by a single distillation, a distillate containing about 60 per cent alcohol; by the use of a rectifying column, it is possible to obtain 94 per cent alcohol by a single distillation.

Some products may be distilled by the direct application of heat to the still; others can only be distilled if a current of steam is passed through the material.

Distillation is the most important process in the manufacture of alcohol, acetic acid, acetone, and most essential oils.

Centrifugal Separation.—The tendency for certain materials to separate by the action of gravity is enormously increased by the application of centrifugal force, which is obtained by whirling.

Centrifugal force depends principally upon the rate of spinning of the centrifuge but is also dependent to a less degree on its diameter. Some centrifuges can be operated at 40,000 revolutions per minute (r.p.m.) and increase the pull of gravity several thousand times. Thus materials which require days for settling naturally will separate almost instantly under powerful centrifugal action.

Some centrifuges are continuous. Other forms are not continuous and must be charged before whirling and cleaned after the operation is completed. Centrifugal force is used in the clarification of fruit juices, the separation of oils from water and fruit juice, and the separation of crystals from mother liquors.

Crystallization.—Cream of tartar and certain organic acids, sugars, etc., are recovered commercially by the application of the principle of crystallization. Crystallization depends upon concentration of the solution to such a point that it becomes supersaturated. The solute then separates slowly as very small crystals. As the concentration proceeds, these crystals grow in size. They usually separate as pure compounds; however, a certain amount of the "mother liquor" or solution clings to the crystals, and then they must be redissolved and recrystallized.

Sifting.—Mechanical sifting is used to separate coarse from fine materials. It is of most use in threshing various cereals but also may be used in separating grape seeds from the skins and stems and has other uses in the horticultural industries.

Conversion of Raw Materials into New Products.—Many raw products must be transformed into new products by processes, some of which are chemical in nature and others mechanical.

Fermentation.—Fermentation, one of the most important processes used in the manufacture of valuable products from raw material, may be caused by any one of three main groups of microorganisms classified earlier in this book, *i.e.*, by yeasts, molds, or bacteria. The products of fermentation of most importance are alcohol, acetic acid, lactic acid, butyl alcohol, citric acid, and acetone.

Alcoholic Fermentation.—Alcoholic fermentation is essential in the manufacture of denatured alcohol and vinegar and all fermented beverages.

Pure Cultures.—The most important means of control of alcoholic fermentation is by the addition of a starter of the desirable type of

yeast. Industrial pure culture methods and other factors will be described in Chap. XXIV.

Other Fermentations.—Other fermentations are controlled by methods similar to those used in the control of yeast fermentation. The details of these methods will be discussed in later chapters dealing with the commercial application of these fermentations. The most important of these fermentations are vinegar fermentation, lactic acid fermentation, butyl fermentation, citric fermentation, and the various starch hydrolysis fermentations caused by starch-splitting molds.

Hydrolysis.—The hydrolysis of starch by the use of enzymes or by acids to maltose or dextrose (glucose) is one of the most important hydrolyzing reactions used industrially. Malt from barley is most commonly used for the hydrolysis of starch to maltose, and acids are generally used in the manufacture of glucose from starch.

The manufacture of bitter almond oil from apricot, peach, and almond pits depends upon hydrolysis of amygdalin by emulsin, an enzyme occurring in the kernels.

Other Processes.—Vegetable oils are refined by treatment with various chemicals, and objectionable flavors and odors are removed with a current of air or by steam.

A very important industry, more or less allied to the horticultural industries, is wood distillation followed in the preparation of charcoal. This process is carried out at temperatures which cause the wood to decompose with the formation of wood alcohol, acetone, acetic acid, water, and tar which last contains valuable by-products. Charcoal remains in the retort. At some future period it may be profitable to utilize fruit hulls, pits, and prunings from orchards and vineyards in this way.

Some organic acids, such as citric and tartaric acid, are recovered from fruit juices by precipitation as insoluble calcium salts.

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CHAPTER III

BRIEF HISTORY OF CANNING

Canning may be defined as the preservation of foods in hermetically sealed containers by sterilization by heat. In its broader sense it includes preservation by sterilization in glass containers as well as in tin cans.

Discovery of Sterilization.—Although Nicholas Appert is to be credited with the discovery of the art of canning, his discovery was made possible by the investigations of the pioneers of bacteriology; among whom may be mentioned Fracastorius, Leeuwenhoek, Needham, Spallanzani, and Scheele.

The theory of "spontaneous generation" formed the basis of a controversy between the scientists of the period dating from about the middle of the eighteenth to about the middle of the nineteenth century and resulted in the classic experiments of Spallanzani, who first demonstrated that food could be preserved by heat. Those who espoused the spontaneous generation theory believed that microorganisms could develop spontaneously in a sterile medium without the addition of any living cells. For example in 1745, Needham, an English scientist, boiled meat extract in a flask and sealed it airtight. Several weeks later he opened it and found it teeming with bacteria. Since he had boiled the extract, he naturally concluded that he had killed all living organisms present. By sealing the flask he thought he had prevented the entrance of living organisms.

Spallanzani demonstrated the fallacy of Needham's experiments in 1765 by showing that various extracts thoroughly heated in sealed flasks did not spoil, unless "air not treated by fire" entered the containers after sterilizing. Although other scientists did not accept his results as final, he was, nevertheless, the first of whom we have record to preserve perishable food products by heat. He concluded that unheated air was in some way responsible for infection.

Scheele, a brilliant Swedish chemist, in 1782 applied sterilization by heat to the preservation of vinegar by boiling it and sealing it hot in bottles.

Nicholas Appert.—Appert, known as the "father of the canning industry," obtained his early training in confectioners' shops, large kitchens, breweries, and distilleries. He was a skillful chef and confectioner before he undertook his investigations in food preservation.

In 1795 he began his studies on food preservation, stimulated by an offer of a prize of 12,000 francs from the French Government for better methods of preserving food for Napoleon's armies and navy. Not until 1804 was he successful in preserving foods in sealed glass containers. He continued his experiments and in 1810 published his results in a book entitled "The Art of Preserving Animal and Vegetable Substances for Many Years," which has been translated into English by Mrs. K. G. Bitting.

The essential points of his process consisted in packing the food product with water into wide-mouthed glass bottles and corking loosely; placing in a water bath and heating at or near the boiling point for the required length of time; removing the bottles from the water bath and finally sealing by driving the corks tightly into the bottles. He considered glass "as the matter most impenetrable to air," and believed that "external air" as such was the cause of spoilage, although he believed air subjected to heat in the glass jars was not capable of causing spoilage because "it had been rendered of no effect by the action of the heat." He apparently had no clear conception of the relation of microorganisms to spoilage and of the real significance of sterilization.

The results of his work spread rapidly, and his methods were soon applied in other countries. It has been claimed that investigators in other countries solved the problem of the preservation of food by heat simultaneously with Appert, or before his discovery. However, it is probable that his work antedates that of others. Incidentally Appert won the prize of 12,000 francs offered by the French Government.

Appert founded a cannery and put his methods to commercial use. The "House of Appert" is still an important canning organization in France and famous for the high quality of its canned products.

Early History of Canning in England and Holland.—In 1807 Saddington presented a paper before the English Society of Fine Arts, entitled "A Method of Preserving Fruits without Sugar for House or Sea Stores." The process was essentially Appert's, in which the fruit was placed in loosely corked bottles and heated in a water bath at 75°C. for 1 hr. After this treatment the bottles were removed, tightly corked, and the corks sealed with cement.

In 1810 Peter Durand obtained a British patent for a process of preserving "animal, vegetable, and other perishable foods" by heat followed by hermetical sealing in "vessels made of glass, pottery, tin, or any metal, or fit materials." According to Bitting this is the first mention of use of the tin container for sterilized foods.

Tin containers had been in use in Holland, however, before 1800 for the packing of salted and kippered fish. The fish was not sterilized

but was preserved with brine and smoke and packed into cans which were filled with hot butter or olive oil and sealed.

Early History in America.—Ezra Daggett is credited with being the first canner in the United States. He learned the art in Europe and canned a few salmon, lobsters, and oysters in New York. Thomas Kensett also began the canning of sea foods in New York in 1819. In 1817 William Underwood, founder of the present William Underwood Company of Boston, Mass., came to America from England, where he had served an apprenticeship at pickling and preserving in the plant of Mackey and Company of London. It is not known at what date he started his canning operations, but as early as 1821 he was shipping goods to South America. Entries in his sales book for 1822 show that he was in that year selling fruits and berries in glass containers. His sales at first were small because of the prejudice in favor of the English goods, it being necessary to sell in foreign markets at prices below those of the English products or to sell under an English label. In many cases he consigned his products to sea captains who sold them for him in South American or Oriental ports and purchased sugar or other supplies for him, the captain receiving half the profits.

Winslow.—Corn was first canned by Isaac Winslow, a sea captain of Maine who packed the corn in cans and attempted to sterilize it in boiling water. Most of the cans spoiled, although a sufficient number kept to encourage him to continue his experiments, and in 1853 he attained sufficient success to warrant application for a patent which was regarded with such distrust by the Patent Office that it was not granted until 1862. At first he canned the corn on the cob, but this was so bulky that he resorted to cutting the kernels from the cob. His work and that of the other early canners of corn in Maine gave that state a reputation for the high quality of its canned corn that endures to the present day.

Middle West.—In the Middle West the first cannery of which we have record was established in 1860 by Thomas Duckwall near Cincinnati, Ohio, for the canning of tomatoes. He later canned strawberries, peaches, and other products. The world-famous Van Camp Company had its beginning at Indianapolis in 1861. Fruits and vegetables were at first packed in 5-gal. cans and sold to grocers, who opened the cans, sold the products at retail and returned the empty cans to Van Camp. This cannery later specialized in canned beans and soups. After 1876 many canneries were established in Middle West, until it has now become the principal producing region in the United States for the canned vegetables, corn, peas, and tomatoes.

California.—In California the first canneries were established in 1859–1860 by Provost and Cutting. Both canneries packed fruits

in glass and in tin and shipped them by vessel to eastern ports. Tin plate was imported by vessel from tin plate factories in the East. The industry in California has developed from an output of about 5,000 cases per year in 1860–1863 to an annual production of approximately 24,000,000 cases of canned fruits and vegetables per year. The pioneers in California specialized in canned fruits, and these are still the most important canned products of that state.

Effect of Civil War.—The problem of feeding the Union armies during the Civil War forced a rapid development of the canning industry. Previous to 1861 sterilization of vegetables and meats had been accomplished in boiling water, which required 5 to 6 hours' time and limited the capacity of the plants to 2,000 or 2,500 cases per day. In 1861 Isaac Winslow found that he could obtain a temperature of 240°F. by adding calcium chloride to the water. He was thereby enabled to reduce the processing time to 25 to 40 min. for many products. This reduction in processing time greatly increased the output of the canneries and did more than any other single improvement in canning methods to speed up the production of canned foods. Their widespread use of canned foods by the federal forces did much to popularize them and to stimulate the growth of the canning industry following the close of the Civil War.

History of the Tin Can.—According to Underwood, in the early years of the industry tin containers were known as "tin cases" or "tin canisters." On the cannery books "canisters" was shortened to "cans," merely as an abbreviation. In time this abbreviation came to be used in place of the longer word "canister." In the British Empire the container is known as a "tin" and canned foods as "tinned foods."

Early Cans.—The first cans were made entirely by hand, the body for each measured and marked on the tin plate and then cut from the sheet by hand shears. The edges were butted together and sealed with a heavy ridge of solder about ⅛ in. thick, making what was known as a "plumb joint." The ends of the cans were also marked on the tin with shears. At first the ends were soldered to the bodies by plumb joints without lapping of the tin. Later the edges of the ends were turned up by means of a mallet and a piece of iron, known as a "heading stake," and the edges of the body of the can lapped to facilitate soldering and to make a better seal.

In 1823 Angilbert in France improved the method of using tin cans by puncturing a small hole in the lid. In using, the food was packed into the improved can, the lid soldered in place and the small vent hole allowed to remain open while the can was given a preliminary heating to expel air. The hole was then sealed with a drop of solder.

Can making was formerly an extremely slow process compared with present standards of production. One expert tinker could then produce 60 cans per day; the average was probably less than this. The cans were made in the cannery, there being no can manufacturers who were not also canners.

Improved Solder Cans.—In 1847 a stamping machine for making can ends with extension edges was invented by Allen Taylor, and in 1849 the pressed top was invented. In 1876 (Stevenson), a machine was invented for automatically soldering the ends to the body of the can by what is known as the "floating" process. About this same date a machine was devised, which clamped the can body around a horn and lapped the edges so that the can maker had only to apply solder to the seam. One man could seam about 1,200 cans per day with the floating machine. Later, 1885, a side seam-soldering device was added to the body-forming machine and the whole can-making process became automatic.

Prior to about 1903 the cans were of the type known as "solder top," or "hole and cap" or "stud hole" cans, whose tops were fitted with circular openings, through which the food was packed. A disk with a small vent hole was placed over the opening and soldered to the top of the can with the small vent open. After a preliminary heating to expel air, the vent was sealed with a drop of solder and the can sent to the sterilizer. At first the disks were sealed to the cans by capping steels, and the vents were also sealed by tipping steels, both by hand work. Later automatic capping and tipping machines were invented and were used in many large canneries.

Sanitary Cans.—The stud-hole can has been almost entirely replaced by the sanitary or open-top can. The ends of this can are fastened to the can body by a double-seaming operation and an airtight seal is made by a lining of rubber or paper between the end and the body of the can. Double-seamed cans without the rubber or paper gasket were made in 1859 as powder canisters, etc., but it was a number of years later before the principle was applied to the sealing of cans as containers for foods.

Double-seamed cans were first used in Europe. A thick rubber gasket similar to those used in sealing glass jars was placed between the can end and body and the end crimped to the body by rollers. This method was known as the "Karges system" and was demonstrated in America at the Columbian Exposition in 1893. The rubber ring used in this method was cumbersome and costly.

Charles M. Ams (Cobb) conceived the idea of lining the edge of the can end with a rubber solution. This greatly reduced the amount of rubber used, simplified the sealing process and revolutionized can making.

Between the years 1894 and 1903 the Max Ams Machine Company developed a line of can making machinery that became commercially successful. Following their demonstration of the feasibility of the manufacture and use of this type of can, its use spread rapidly and many improvements in equipment and container were made. Among these may be mentioned, the inside lacquered can, which is lined with a special lacquer baked on the tin at a high temperature, and "C enamel," which prevents blackening of the can and contents by hydrogen sulfide liberated by corn, peas, etc. Plain lacquer lining protects highly colored fruits and beets against the bleaching action of the metal.

The solder-top cans were objectionable for fruits, because in packing large pieces into the can through the relatively narrow opening much of the fruit was lacerated, and in soldering the cap to the can, some of the syrup became carbonized, forming black specks.

In the sanitary can the diameter of the opening is equal to that of the can body. Fruits and tomatoes can therefore be packed into the cans without crushing or lacerating. Neither solder nor heat is used in sealing the lid to the can; consequently carbonizing of the syrup is avoided.

Evolution of Sterilizing.—The first canned foods were sterilized in boiling water, in some cases 5 to 6 hours' heating at the boiling point being necessary. As noted elsewhere, the calcium chloride bath was introduced in 1861 and made possible the use of temperatures as high as 240°F., with consequent reduction in processing time.

Pressure Sterilizers.—In 1852 the son of Nicholas Appert adopted the use of the autoclave, *i.e.*, a device for the use of steam in an enclosed space under pressure, in canning. This permitted the use of any desired temperature, obviated the cleaning of the cans from the calcium chloride bath and reduced the strain on the cans during sterilization. In 1874 A. L. Shriver, a canner of Baltimore, was granted a patent on a steam-pressure retort for the sterilizing of canned foods. The introduction of steam-pressure sterilization marked a very great advance in the canning of vegetables.

Continuous Sterilizers.—The continuous open cooker was the next notable advance in sterilizer design. The first continuous cooker used in California for fruits consisted of a long, open wooden tank (often 100 ft. long) filled with water maintained at the boiling point by open steam coils. The cans of fruit were carried through the cooker in metal baskets suspended from an overhead conveyer. This method has been superseded by the continuous agitating cooker, in which the cans are carried through a large steam box by means of a reel and spiral in such a manner that the cans roll continuously and thus agitate the contents. Heat penetration, on account of the agitation, is very rapid and the time of process-

ing, therefore, has been greatly shortened for most fruits and for tomatoes.

Recently a continuous-agitating pressure sterilizer for sterilizing cans in a retort under steam pressure has been perfected. It permits the use of very high temperatures and a very short sterilization and may in time revolutionize temperatures and times of sterilization for spinach, pumpkin, corn, and other vegetables.

Development of Conception of Sterilization.—The early canners, including Appert, believed that the preservation of canned and bottled foods depended upon the exclusion of outside air, because they found that air sealed in the container and heated became harmless insofar as causing spoiling was concerned. It was believed that air itself caused spoiling of the canned product and that heating in some mysterious manner destroyed its power of causing decomposition. These men recognized the facts in the case but did not realize that living organisms in the air and not the air itself caused spoiling.

Vacuum Theory.—A later theory was that the vacuum in the can prevented spoiling and therefore great care was taken to make the vacuum as nearly complete as possible by repeatedly heating, venting, and sealing the cans to remove as much of the air as possible. The vacuum theory persisted among commercial canners until very recently. It is true that removal of air from the container aids greatly in the preservation of unsterilized fruit and vegetable products by checking the growth of aerobic organisms such as molds. In general, however, a vacuum does not necessarily make sterilizing easier, and its importance in this connection has been overestimated.

Pasteur.—Pasteur by his experiments on pasteurization and sterilization about 1860 definitely proved that microorganisms are the real cause of spoilage and that heating canned or bottled foods preserves them by killing the microorganisms. He found that microorganisms varied in their resistance to heat and that the character of the food product affected the temperature of sterilization. He introduced "pasteurization," *i.e.*, heating food products to a high enough temperature to kill the majority, but not all, of the microorganisms present, thereby greatly prolonging the normal keeping quality of such products.

Pasteur exploded the spontaneous generation theory and showed the fallacy of the vacuum theory.

Early Spoilage Studies.—The first bacteriological study of the spoiling of canned foods in America was made in Wisconsin in 1895 by H. L. Russell, who proved that the heavy spoilage losses experienced by the pea canners of Wisconsin were caused by spore-bearing heat-resistant bacteria. He isolated the organisms and eliminated most of the spoilage by increasing the temperature of sterilization.

The spoilage of canned corn was studied by Prescott and Underwood in 1896 with results similar to those obtained by Russell with canned peas.

Since the work of these three men, frequent contributions to the knowledge of sterilization and spoilage of canned foods have been made, and most commercial canners are familiar with the fundamentals of bacteriology as applied to canning.

Recent Studies.—The research of Dickson of Stanford University, Meyer of the University of California, and Esty of the National Canners Association on *Bacillus botulinus* has resulted in the establishing of safe temperatures and times of sterilization of nonacid canned foods. That of the National Canners research staff on thermophilic-spoilage bacteria has modified the procedure in the canning of peas and corn to an important extent.

Development of Special Machinery and Methods.—It will not be possible to trace in detail the development of the many special machines used for the preparation of raw products for canning, although in some cases reference will be made in later chapters to the evolution of certain equipment and processes. The canning of corn and of peas has evolved from hand preparation to methods that are conducted almost entirely by automatic machinery. Peaches are no longer peeled by hand, special lye-peeling machines now being used; pumpkin is now handled by machinery; and special machines have been developed for peeling and coring apples and for pitting peaches. In general the tendency has been toward the displacement of hand labor by automatic machinery, until today the commercial cannery has become a large and intricate machine shop, requiring the services of a large corps of skilled mechanics.

An excellent review of the history of canning will be found in "A History of the Canning Industry," published in 1913 by The Canning Trade, of Baltimore. Additional historical notes are given in the ensuing chapters on can making, canning of fruits, and canning of vegetables.

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CHAPTER IV

TIN AND GLASS CONTAINERS

While Appert used glass containers in his experiments and in his "cannery," the tin container during the past hundred years has largely displaced the glass container in the commercial "canning" of foods. On the other hand, glass is the usual container for commercially produced jams, jellies, preserves, green olives, and various kinds of pickles. In the household the glass container is used to the practical exclusion of the tin for home preservation of fruits, vegetables, meats, preserves, etc. It is also the commercial container for fresh milk, catsup, and wines, and large quantities of glass bottles are used for fruit juices and beer. At present each container is invading the other's fields; thus, much beer is now preserved in cans, and glass jars that will withstand processing in an agitating sterilizer are now being successfully used for "canned" fruits. Cans, for the time being, have replaced glass containers for pasteurized pineapple, grapefruit, and orange juices, and the glass jar is now competing with the tin can as a container for vacuum-packed coffee. It is estimated that more than three billion cans are used as containers for foods annually. Probably an even greater number of glass containers are used if one includes those used commercially for milk and beer and in home food preservation.

TIN CONTAINER

Tin coated vessels have been known since ancient times. They were mentioned by Pliny prior to A.D. 23, according to Macnaughton and Hedges. They relate that according to legend a Cornish tin miner migrated to south Germany in medieval times, and there discovered tin in the Erzebirge mountains about 1240. The date of the discovery of the process of making tin plate, they state, must have been between 1240 and 1575, since tin was being exported to Germany for the manufacture of tin plate in the latter year. The south German (Bohemian) producers guarded the process for about 300 years, and it was not until about 1625 that the secret was obtained by the Duke of Saxony, where the industry soon became more important than in Bohemia. About 1665 an attempt was made to make tin plate in Great Britain, but not until 1720 to 1730 was the manufacture of tin plate in that country successfully established. Hanbury at Pontypool is credited with the first successful commercial production of tin plate in Great Britain. At first

tin-plate was produced in various parts of that country, but in recent times it has been confined to Wales.

Tin-plate manufacture began in France also early in the eighteenth century, about 1714.

For many years the United States imported most of its tin plate from Cornwall and, according to Macnaughton and Hedges, not until 1873 was much progress made in commercial production in America. The McKinley tariff in 1891 included protection for American tin plate and gave the struggling industry the impetus required to enable it to reach its present great size.

While Cornwall was for several centuries the world's principal source of tin, since about 1870 the Malay States have become the most important source of this metal. Certain sections in South America also produce important amounts of tin.

Macnaughton and Hedges give the following description of the making of tin plate in Saxony. In the early centuries of tin-plate making, iron bars were hammered into thin sheets by hand. Later a number of the fairly thick sheets were hammered in bundles. The iron oxide scale was removed by rubbing with sandstone, followed by soaking in liquids acidified by fermentation. From this practice probably comes the modern term "pickling," which signifies treatment of the black plate in dilute sulfuric acid to remove oxide scale. The plates were scoured in water and sand and then stored in water until taken to the tinning pot. Three pots were used. In the first or "soaking pot" of molten tin the plates were soaked for an hour or less; in the second, the "wash pot," they were redipped a short time to give a more uniform coating; and in the third, the "list pot," the ends were dipped to melt and remove excess tin from the edges. The plates were then cleaned and polished with sawdust and moss. Later the molten tin in the soaking pot was covered with melted fat to prevent oxidation. The iron ore in Saxony was reduced to iron by heating with charcoal. Charcoal was subsequently replaced by coke in English practice. Hand hammering was replaced by rolling the bars mechanically to form plate.

During the nineteenth century dilute sulfuric acid replaced fermented liquids for pickling both the black plate and the descaled plate; Bessemer steel replaced iron for making the plate; special annealing methods for the steel plate were introduced; and zinc chloride flux came into use to facilitate union of the tin with the prepared steel plate surface.

In the present century several important advances have been made. Some of these are: invention and perfecting of the sanitary double-seam can, improved baked-enamel coatings, cellulose-lacquer linings, special wax linings, zinc oxide-containing enamels for corn cans, and the recently developed cold-rolled plate which is very resistant to corrosion.

In the following paragraphs are outlined briefly the various steps in making ordinary tin cans for use as food containers.

Hot Rolling.—Tin plate consists of approximately 98 per cent iron and about 2 per cent tin. Bessemer steel or open-hearth steel of the highest grade and very low in carbon is used.

The preparation of the iron plate begins with bars about 8 to 9 in. wide and 30 to 40 in. long. The "gauge" or thickness of the final sheet depends upon the thickness of these bars. The bars are usually $\frac{3}{16}$ to $\frac{3}{8}$ in. thick. Two such bars are heated to a cherry red and passed through a set of rolls four times, resulting in two sheets about 30 in. long. These two sheets are placed together, heated to cherry red and rolled to about 60 in. in length. They are then doubled in the middle, giving four sheets, which are pressed lightly together, heated again, rolled to the required length and allowed to cool. The usual length is 84 in., which gives three packs of four sheets, 20 by 28 in. each.

Black Pickling.—The pack, four sheets thick, is cut into three sections 20 by 28 in. in size. The sheets are then carefully separated and placed in a tank of dilute sulfuric acid, known as the "black pickle," which is maintained at the boiling point by steam. The sheets are allowed to remain in the pickling solution until all scale and dirt are removed and are then washed in water. In some cases the sheets are passed through two tanks of acid. The pickling solution dissolves iron oxide from the surface of the sheet so that the tin will adhere smoothly and uniformly. Imperfectly pickled sheets are sorted out and returned to the pickle after cleaning.

Annealing.—The sheets are next placed on annealing stands holding 4 to 6 tons, and covered with an airtight cast-iron cover. They are then heated to 1500 to 1800°F. for 18 to 24 hr. with as complete exclusion of air as possible. Annealing toughens the plate and prevents its breaking.

Cold Rolling.—The sheets are then rolled between three sets of polished rolls and annealed a second time for a short period and at a lower temperature. Cold rolling makes the surface of the sheets smooth and thus reduces the amount of tin necessary for coating.

White Pickling.—The annealed plates are given a short "pickling" in dilute sulfuric acid and are stored under water until they are tinned. This second pickling process is known as "white pickling" and is for the purpose of roughening the surface of the plate slightly, so that the tin will adhere satisfactorily.

Plating.—The tin pot is a U-shaped metal box equipped with two or three sets of rolls and filled with molten tin. A layer of flux floats on the molten tin where the sheets enter the pot and a layer of palm oil where the sheets emerge. In some cases the tin and palm oil are

in separate containers. The sheet is drawn through the flux, tin, and oil by the rolls. The flux prepares the plate to receive the tin and checks formation of oxide of tin on the surface of the molten metal. The oil gives finish and luster to the plate.

The thickness of the tin coating is regulated by adjusting the distance between the rolls and by the speed with which the sheets are drawn through the bath. The slower the speed the thinner the coating will be, because the longer the plate remains in the tin the hotter it becomes and the smaller the amount of tin which will be chilled to it.

Branning.—The tinned sheets are polished and cleaned in the branning machine, which consists of a series of small rollers covered with woolly sheepskin and running in middlings or bran. The rolls and middlings or bran polish the plate and remove adhering oil. A soda solution also may be used to clean the plates and remove the oil.

Grading and Sorting.—The polished sheets are carefully sorted to remove defective sheets for replating and perfect sheets are packed into boxes, 112 sheets per box, which are shipped direct to the can factories.

Grades of Tin Plate.—Ordinary tin plate is known as "coke plate" and carries about 1½ lb. of tin per base box of 112 sheets 20 by 28 in. in size. Charcoal-A or Char-A plate carries about 2½ lb. of tin per base box and is used extensively in cans for fruit canning. Heavier tin plate than Char-A is made but is not commonly used for the manufacture of cans for the food canning industries.

Different weights of plate are designated by letters, *e.g.*, IC, HX, IX, IXX, IXXX, IXXXX, the last being the heaviest of this series and IC the lightest in weight. For example, a box of 225 sheets of IC plate of 13¾- by 10-in. size weighs 147 lb. and the same number of IXXXX plates weigh 203 lb.

Lacquering.—Highly colored fruits and beets bleach in plain tin cans but retain their color fairly satisfactorily in lacquered cans.

Lacquer is applied in solution in alcohol to one side of the plate. The plates then travel on an endless conveyer through a long oven where they are heated to about 450 to 500°F. to dry and to bake the lacquer. Baking causes the lacquer to become a clear golden-brown color.

The lacquered sheets are then formed into cans in the usual manner to give single-lacquered cans. The stamping, lock-seaming, flanging, and double-seaming operations used in can making abrade the lacquer more or less and expose the tin in small areas. The interior of some of the cans is sprayed with a solution of lacquer and again baked to give "double-lacquered" cans. These double-lacquered cans are especially desirable for sour red berries, such as loganberries. In the canning industry these linings are also known as enamel linings. Recently cellulose compounds

and other synthetic lacquers have been used successfully for beer cans and cans for other special purposes. At present a great deal of experimentation with such linings is under way. A special wax lining is used by one can manufacturer for beer cans. The synthetic lacquers are applied in solution, in a suitable solvent, to the finished can.

Outline of the Manufacture of Sanitary Cans.—The sanitary or open-top can, which is sealed by double seaming without the use of solder, has become the most important food container now used.

Cutting Body Blanks.—The sheets are cut by a slitting machine into strips equal in width to the circumference of the can. These strips are cut crosswise to form the body blanks. The machine used for this purpose is known as a "gang slitter." A slitter and trimmer will produce about 75,000 body blanks per day.

Notching Body Blanks.—Each body blank is notched at the four corners in such a manner that smooth joints are formed at the junction of the two edges of the body, when the lap seam has been made. This smooth union is essential in order that the ends of the can may be smoothly double-seamed to the body without danger of leaks.

Lock Seaming.—The flat can body passes through an edging device, which is usually part of the lock-seaming machine. The edges are turned back and when the can body is turned around the horn or mandrel, these edges hook together. The body is bent around the horn by "wings," moving metal sheets. A hammer drops upon the locked edges and flattens them, forming the lock seam. Since the lock seam is not water- and gas-tight, the can body is carried forward in such a manner that the seam passes through flux and molten solder. The excess solder is then removed by brushes and the can bodies cooled by a blast of air.

Flanging.—The can bodies next pass through a flanger, a machine equipped with convex plungers, which are forced a short way into the open ends of the can body, forcing the edges outward to form the flanges, which are to receive the ends.

Forming the Ends.—A machine known as a "scroll shears" cuts the tin plate into strips of a pattern resulting in a minimum of waste.

A stamping machine known as an automatic vacuum "strip feed press" receives the strips and stamps out the disks which form the ends of the cans. It also forms the panels, concentric circular ridges, and depressions on the can ends, giving rigidity to the ends and reducing bulging. The edges are still flat. From the press the ends pass to the end-curling machine which curls the edges of the can ends inward.

The Gasket.—A solution of rubber composition in benzene or toluene is placed in the groove of the can end and is dried quickly by heat. A film of rubber composition is left in the groove and forms the "rubber gasket."

Instead of the rubber composition, a paper gasket may be cut from thin spongy cardboard and fitted to the groove; although the paper gasket is used but little at present for food containers.

Sealing the Ends.—The can bodies and one end are brought together in the double seamer. The can body enters the double seamer in a horizontal position; the end is applied automatically and small rollers pass around the edges of the end and can body, folding the flanges of the end and can body as shown in Fig. 4, No. 2. A second pair of rollers then pass around the edge of the can and tightly compress the folded flanges together as shown in Fig. 4, No. 3. To form an airtight seal, pressure at the same time is exerted against the end of the can, forcing the gasket tightly against the end.

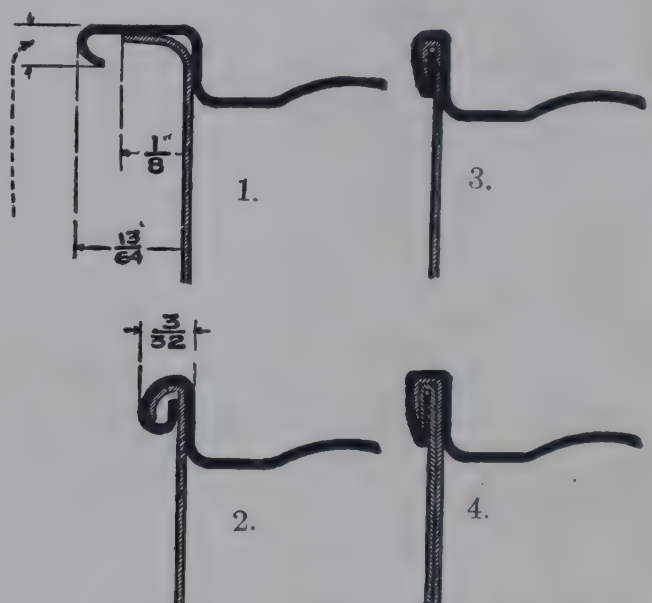

Fig. 4.—Steps in sealing a sanitary can. 1, Lid in place; 2, lid after first operation; 3 and 4, after second operation. (*Courtesy Cameron Can Machinery Company.*)

The end sealed to the can in the can factory is known as the "factory end" and that sealed in the cannery, the "cannery end."

Testing for Leaks.—The finished cans are fed to a testing machine, which automatically places the open end of the can against a large rubber gasket and applies air pressure. Leaky cans are thrown out by the machine. The defective cans are tested further by workmen who repair the leaks and again test the cans before they are sent to the warehouse or cannery.

Can makers usually guarantee that there will be less than one defective can in 1,000.

Cold-rolled Plate.—It has been found that steel very low in phosphorus and low in silicon and carbon can be cold-rolled successfully to give base plate that fabricates well in can making. Special, costly rolls are required, since the cold plate cannot be doubled into bundles for rolling; hence only the largest steel-plate manufacturers have undertaken its

production. The plate is rolled in a single sheet. It is of finer crystalline structure than the hot-rolled plate. Also it is usually softer and more homogeneous.

When tinned and made into cans, it is much more resistant to corrosion by acid food products than is ordinary hot-rolled tin plate. For this reason it is coming into rather general use for cans for such products as cherries, berries, and apples.

Its composition compared with that of hot-rolled steel plate is about as follows:

Constituent	Type L plate, per cent	Plain coke plate, per cent
Carbon	0.067	0.10
Manganese	0.370	0.35
Sulfur	0.032	0.040
Phosphorus	0.004	0.012
Silicon	0.003	0.005

Courtesy of American Can Co.

Sizes of Cans.—Tin cans are made in a great variety of sizes and shapes, developed by trade custom rather than by the needs of the consumer. Certain sizes, however, are known as "standard," and the

Table 1.—Size and Capacity of Standard Cans

Number or name	Diameter, inches	Height, inches, sealed can	Capacity, ounces avoirdupois, of water at 68°F., sealed can
5 oz	2⅛	2⅞	4.85
6 oz	2⅛	3½	6.08
8 oz. regular	2¹¹⁄₁₆	3	7.93
8 oz. tall	2¹¹⁄₁₆	3¼	8.68
Picnic; No. 1 eastern oyster	2¹¹⁄₁₆	4	10.94
No. 300	3	4⁷⁄₁₆	15.22
No. 300X	3	4⁹⁄₁₆	15.69
No. 1 tall	3¹⁄₁₆	4¹¹⁄₁₆	16.70
No. 303	3³⁄₁₆	4⅜	16.88
No. 2 flat	3⁷⁄₁₆	2¼	9.21
No. 2 short	3⁷⁄₁₆	4	17.79
No. 2	3⁷⁄₁₆	4⁹⁄₁₆	20.55
No. 2½	4¹⁄₁₆	4¹¹⁄₁₆	29.79
No. 3	4¼	4⅞	35.08
No. 10	6³⁄₁₆	7	109.43
Gallon	6³⁄₁₆	8¾	138.34
No. 1 square	3 × 3½	3½	17.27
No. 2½ square	3 × 3½	6¼	32.47

dimensions and capacities of these are given in Table 1, as promulgated by the U. S. Bureau of Standards, 1936.

The No. 2 can is used for peas, corn, and string beans and to a limited extent for fruits. The standard cans for fruits are the Nos. 2½, 2, 1 tall, and 10 and the 8 oz. Numbers 2½, 3, and 10 are used for tomatoes. The No. 10 is used for pie fruits and for fruits and vegetables of all varieties and grades for hotel and restaurant use. The full-gallon (No. 12) can is used to some extent for olives and to a very limited extent for other fruits and vegetables. The Nos. 1 tall and 2 and the 8-oz. cans are becoming

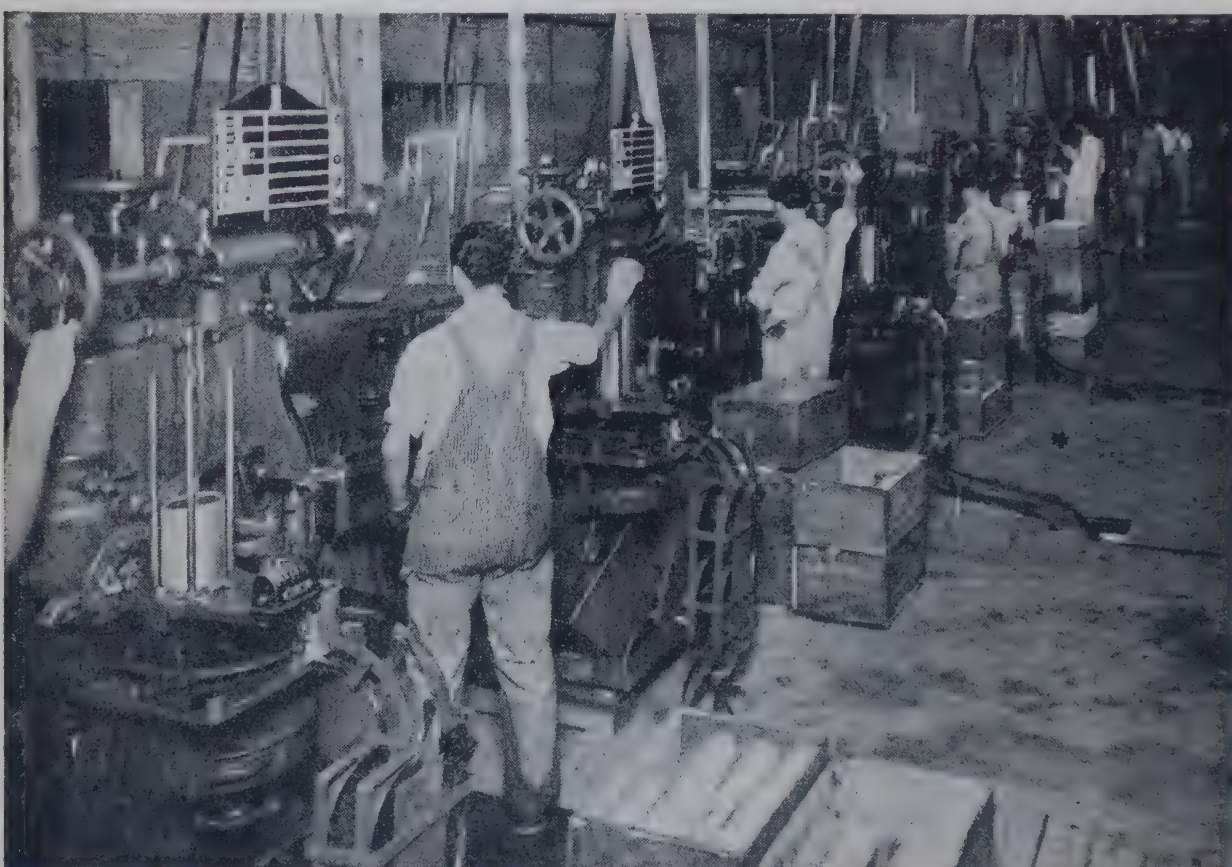

FIG. 5.—Battery can-sealing machines. (*Courtesy Libby, McNeill and Libby Co., California.*)

more popular for fruits because they are the more suitable sizes for the small family.

For tomato juice the Nos. 300, 300X, 303, 1 tall, and 2 cans are popular. The 8-oz. cans are used extensively for canned fruit cocktail. For pineapple juice the Nos. 1 tall, 300, 303, and 2 are commonly used. Tomato and pineapple juices are also packed in a large can known as No. 5. There are a number of other special cans such as the ovals used for fish, the flat 2½, the tall quart, the tall pint for olives, and others.

The writer believes that the sizes and styles of cans could be advantageously reduced. The present great number of shapes and sizes of containers is confusing to the purchaser and increases the cost of production, because of the special and extra equipment needed for sealing, filling, and otherwise handling the different types of cans.

GLASS CONTAINERS

The glass container possesses the advantages that there is no metal to react with the food product, the customer may see in the unopened container what he purchases, and the container is refillable. It has the disadvantages that it is heavier and more fragile than the tin container. Its uses in the food industries have been mentioned.

Glass was known to the ancient peoples of the Mediterranean basin as early as 1600 B.C. The first glass was made by mixing sand and the ash of seaweed, covering with clay, and heating in a furnace. After cooling the ball of pottery was cracked open to secure the lump of glass. Later the ingredients were mixed, wet-molded, and burned in the same manner as clay. Still later, in the time of the Roman Empire, glass was melted and blown into bottles and ornaments. The next advance consisted in blowing it into molds, at first of wood and later of cast iron. In 1880 the Owens automatic bottle-blowing machine, using compressed air instead of air pressure produced by human lung power, was introduced. Most glass food containers used in the United States are now made in this manner or by molding by pressure.

Composition.—Glass may be defined as a mutual solution of suitable silicates formed by heat and fusion, with subsequent cooling to prevent crystallization. Part of the silicate may be replaced by borate or phosphate. Glass for food containers usually consists of silicates of sodium (or sodium and potassium), calcium, and magnesium. Its composition is usually given in terms of the respective oxides. Increasing the magnesium oxide and decreasing the sodium monoxide content increase the hardness of the glass. A typical composition of glass for fruit and vegetable products is as follows:

	Per Cent
SiO_2	74.25
CaO	7.00
MgO	0.70
Na_2O	18.05
Fe_2O_3 and MnO_2	traces

Some of the Na_2O may be replaced by K_2O.

Glasses for special purposes contain other elements. Thus barium gives a heavy glass of high refractive index, useful in optical instruments. Lead imparts weight and brilliance to cut glass. Zinc imparts toughness and heat resistance. Boron is used in certain chemical glassware, such as Jena ware.

Color is imparted by various elements. For example, ferrous iron gives a green glass, ferric a brown, chromium a green, manganese dioxide a pink, cobalt a blue, cadmium sulfide a yellow, carbon an amber, and uranium a fluorescent yellow glass.

The Mix.—The alkali and alkaline earths in the form of the carbonates are mixed with silicon dioxide sand of high purity, together with a very small amount of manganese dioxide. The manganese dioxide is necessary to counteract the amber color imparted by the small amount of ferric oxide always present in the raw materials. The pink of the manganese compounds counteracts the amber of the ferric compounds, to give a clear glass.

In some cases feldspar is used in place of part of the carbonate. The following is an example of such a mix.

	Pounds
SiO_2 (sand)	1,000
Feldspar	100
Soda ash (carbonate)	350
Limestone containing some $MgCO_3$	200

A small amount of manganese dioxide is added, the amount varying with the iron content.

The various powdered or ground ingredients are thoroughly mixed in the dry condition. The mix is made up on the basis of accurate chemical analyses of the raw materials, including their moisture content.

Melting.—The mix is melted in a long furnace lined with firebrick and fire clay. Owing to corrosion of the lining, the furnace must be rebuilt occasionally. Natural gas or petroleum is the usual fuel. The carbonates give up their carbon dioxide, which bubbles out of the molten mix. The molten mass flows beneath an obstruction to the opposite end of the furnace, from which it may be drawn to the bottle-blowing machine or glass-molding machine. The ingredients of the mix must be completely melted and thoroughly blended before the molten glass is drawn off for making of containers.

Bottle Blowing.—A small, measured amount of the viscous molten glass is dropped automatically or drawn by suction into a cast-iron mold which cools it slightly and delivers it to a second mold where compressed air automatically blows it to the size and form of the mold. A blast of flame then fire-polishes the mouth of the bottle. The mold with the newly blown bottle is carried automatically by a circular path to the delivery point. During this brief period the glass hardens sufficiently to permit the bottle to be removed automatically from the mold and placed on the slowly moving woven metal cloth conveyer, which carries it to the "lehr," *i.e.*, the annealing oven. For a few moments it remains "red hot" after removal from the mold. Most jars are formed in similar fashion.

In forming ordinary jelly glasses the molten glass may be pressed into a metal mold by a plunger.

Annealing.—Annealing or "tempering" is the most important step in the making of glass containers used for foods preserved by heat; because upon it depends the resistance of the glass to breakage by rapid changes in temperature occurring during the processing and cooling of glass-packed food products. If glass is cooled too slowly it may devitrify, *i.e.*, crystallize, becoming grainy and weak. If cooled too rapidly, or if cooled irregularly, it will be under irregular strains and is apt to break, even with small rapid changes in temperature.

Annealing consists in cooling the glass slowly and regularly until it has become solid. In commercial practice the containers pass by a metal conveying belt through a long brick tunnel heated by electricity or a gas flame under very accurate automatic temperature control. Electrically produced heat permits of more careful regulation than that produced by combustion; consequently most of the modern lehrs are electrically heated.

The containers, as they travel forward, are first slowly heated to incipient softening, possibly 900 to 1000°F. for food containers. They are held at this temperature for a few minutes and are then slowly cooled by passing through sections of the lehr of progressively decreasing temperature. They emerge at the outlet end of the lehr sufficiently cool to be handled comfortably with heavy gloves.

Frequent tests are made in the glass-plant control laboratory to determine the resistance of the containers of each day's run to the shock of rapid heating and cooling. Remarkably tough and resistant glass containers for foods are now available. They have even been used successfully in an agitating, continuous cooker of the type used for canned fruits. Such containers are the result of extreme care in annealing as well as careful chemical control and accurate operation of the furnace.

Defects of Glass.—Glass that has remained an insufficient time in the furnace may be "seedy," *i.e.*, contain small bubbles of carbon dioxide gas. "Stony" glass contains small, unmelted fragments of the raw mix. If not well melted and blended previous to blowing, the glass may be "cordy" or "wavy" in appearance. If devitrification (crystallization) has occurred, the glass may be "sandy" in appearance and friable. "High color" (pink) is due to too much manganese dioxide in the mix and "low color" (green) to too much iron. Brittleness and low resistance to temperature change are usually due to poor annealing.

Occasionally bottles or jars will exhibit thin areas or thick bottoms because of improper blowing. These defects can be corrected by having the molten glass at the proper temperature and viscosity when blown and by operating the glass-blowing machine at proper speed and air pressure.

Types of Containers.—The simplest food container is the familiar press-molded jelly tumbler used in the home. The jelly is sealed (although ineffectively at best) with melted paraffin, and the jar is covered

with a nonhermetic (not airtight) tin cover. For home use there are now available jelly glasses that may be hermetically sealed with lids similar to those used for mayonnaise jars.

The Anchor jar resembles the simple home-style jelly glass in outward appearance, except that it carries a "bead" around the top for the purpose of holding in place a lid which is crimped to the jar in a manner similar to the double-seaming operation of sealing a can lid to a can. However, the seal is made by compressing a soft rubber band between the edge of the lacquered metal cap and the side of the jar. The jars are sealed under vacuum. The closure holds very satisfactorily during pasteurization and is used very successfully in processing in retorts at temperatures above 212°F., provided air pressure is used in the retort to hold the lids in place. This is true of other closures also.

The band cap, typified by the Phoenix hermetic closure, may be applied under vacuum or at atmospheric pressure. A metal band crimped over a heavy bead holds against the top of the jar a lid lined with rubber composition similar in texture to that used on can lids. A similar lid is used for fruit jars for home use (Economy and Kerr Mason jars), although it is usually held in place by a screw top. This closure is also used commercially.

The screw-top closures for wide-mouthed mayonnaise and horse-radish type jars are lined with shellacked or lacquered paper which makes a fairly tight seal against the top of the jar. It is not sufficiently airtight for use in preserving foods such as fruits and jams by heat.

The Ball Mason and the E-Z Seal type fruit jars for home use are sealed by rubber gaskets held in place on the shoulder of the jar by a screw cap or by glass top with a strong wire clamp. They are used chiefly in the home.

The tear-off type seal, of which the well known Goldy Seal used for bottled products is a familiar example, consists of an aluminum cap crimped over a cork or composition disk backed by a lacquered tin disk. The aluminum cap may be torn off without use of a special opener. The Hazel Atlas aluminum cap for wide-mouthed jars is similar to the Goldy Seal in appearance and also has the tear-off feature.

The most widely used closure for beverage bottles is the Crown Cap, familiar to all readers as a seal for bottled soda waters, beer, fruit juices, catsup, etc. It is also used for milk bottles, horse-radish jars, and other jars of medium wide mouth. It consists usually of an impervious paper or metal liner which rests against the top of the bottle, a backing of cork or paper, and the outer metal disk of heavy tin plate, which is crimped tightly over the rim of the bottle by a simple downward plunger action.

The White vapor-seal cap, recently adopted for sealing bottled juices, preserves, etc., is applied to the bottle as the head space is filled with live steam. It is a press-on-type lid, the seal being made by a rubber gasket. It has the advantage that it may be used to reseal the bottle after opening.

The so-called "packer cap," used for gallon jugs of cider, for bottled vinegar, and some other products, consists of a cork-lined, heavy, lacquered, tin cap held in place by a "turndown" wire bail. It is also used as a convenient reseal cap for such products.

Screw caps for wine bottles are now made of metal or of molded plastics such as Bakelite. They are lined with cork or shellaced composition disks. They have practically displaced corks as closures for bottled sweet wines in California.

Corks are still used in European countries for all types of bottled wines and in California for bottled dry wines. Only the finest cork should be used for this purpose. Cork oak bark comes from the Mediterranean area, chiefly Spain, Portugal, and North Africa. It is prepared by boiling in water to remove gums, etc., and to soften it. It is then trimmed by machinery and cut by hand-controlled machines into cylindrical corks. Tapered corks are cut from the cylindrical corks by a special lathe-like machine. Before use as wine bottle closures the cylindrical corks are wet with a mixture of about equal parts of glycerin, high-proof brandy, and water and allowed to stand until soft; or they may be so treated and then steamed just before use. The glycerin keeps the cork pliable and soft in the bottle and prevents its sticking to the glass.

There are other types of closures than those mentioned in this section. Glass-container and closure manufacturers are glad to furnish additional information on the subject on request.

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CHAPTER V

GENERAL CONSIDERATIONS IN ESTABLISHING A CANNERY

In establishing a commercial cannery careful consideration should be given to a number of important factors affecting its location for profitable and efficient operation.

Magnitude of Canning Industry in the United States.—According to the last census there were approximately 4,000 canneries in the United States, of which approximately 3,000 were engaged in the canning of fruits and vegetables. Table 2 summarizes some recent data on the canning industries.

The production of some of the more important canned foods in California is given in Table 3.

The increase in production of some of the canned foods given in Table 2 has been very rapid in recent years; with others, growth has been gradual. In 1913 the annual output of canned pineapples was 1,667,000 cases. In 1920 it had become approximately 6,000,000 cases per year, an increase of about 400 per cent in 7 years. The California canned fruit pack in 1900 was 2,873,000 cases; in 1905, 3,450,000 cases; in 1910, 4,774,000 cases; in 1915, 5,731,000 cases; in 1920 it was 11,383,000 cases; in 1933 it was 15,424,000 cases; in 1935 it was 16,457,000 cases; and in 1937 it was 21,517,000 cases. Growth was much more rapid from 1915 to 1919 than from 1905 to 1910. Canned tomatoes in the whole United States have shown considerable increase since 1920, when the pack was 11,368,000 cases. It was 24,289,543 cases in 1935. Peas have increased from 5,577,000 cases in 1908 to 12,317,000 cases in 1920 and 24,698,633 cases in 1935. The 1908 pack of corn was 6,779,000 cases as compared to 15,040,000 cases in 1920 and 21,471,417 cases in 1935.

Canning has become an industry comparing favorably in size with the other important industries of America.

Capital.—The establishment of a cannery involves a heavy expenditure of capital and many canneries have failed for lack of it. Usually the return on the investment is not large; nevertheless, it compares favorably with the returns from investments in other well-established industries.

It is desirable to build a plant well within the means of the builder, and it is a very much better policy to begin with a small establishment and increase its size gradually than to build a plant which is too great a burden upon the resources of the builder.

TABLE 2.—COMPARATIVE UNITED STATES PACKS OF MORE IMPORTANT CANNED FRUITS AND VEGETABLES

(After National Canners' Data)

Product	Number of Cases	
	1935	1936
Asparagus, total	2,519,958	2,787,128
Asparagus, white	1,655,561	1,905,723
Asparagus, all-green	864,397	881,405
Green beans	6,031,152	5,475,399
Lima beans, fresh	1,186,378	1,550,810
Beets	2,461,768	2,490,200
Corn	21,471,417	14,621,189
Peas	24,698,633	16,552,816
Pumpkin and squash	833,355	1,767,847
Spinach	3,482,936	3,318,730
Tomatoes	24,289,543	21,058,928
Tomato juice	9,286,590	13,104,809
Apples and apple sauce	4,218,837	4,876,963
Apricots	3,332,814	2,982,467
Blackberries	486,651	596,341
Grapefruit	3,747,822	2,410,904
Grapefruit juice	2,556,124	2,235,699
Red pitted cherries	2,562,683	1,450,335
Sweet cherries	535,393	569,785
Olives, ripe	640,446	659,814
Peaches	11,746,874	11,509,593
Pears	4,766,874	6,104,365
Pineapple 1933 (7,815,540)	10,561,300	12,793,000
Plums	152,016	116,040
Prunes	1,766,570	1,891,364
Fruit cocktail	1,649,907	2,156,808
Fruits for salad	1,340,547	1,465,186

It is impossible to give the exact amount of capital necessary for a cannery of given size, but it is ordinarily considered that $2,500 capital is required for each 1,000 cans of fruit per day. This sum will vary with the locality, the length of the canning season, the varieties of fruit canned, and other factors.

Raw Products Supply.—In considering the establishing of a cannery, one of the most important factors for study will be the quantity and quality of fruit available for canning purposes. The fruit available must be of good quality and of sufficient quantity to permit profitable operation. It should be possible to can the fruit within 24 hr. after picking.

Markets.—The principal market for canned fruits in the United States is in the region east of the Rocky Mountains and north of the Mason and

Table 3.—Recent California Packs of Fruits and Vegetables
(In Cases)

Product	1923	1933	1935	1937
Fruit:				
Apricots	1,562,298	2,416,267	3,164,452	5,553,213
Cherries	990,000	392,533	133,323	239,871
Olives	675,000	488,000	640,446	659,814*
Peaches, free	872,276	65,144	365,769	1,042,953
Peaches, cling	6,591,335	10,243,976	10,850,492	12,205,478
Pears	872,676	1,927,564	1,386,651	1,499,024
Plums	164,402	110,017	123,733	179,718
Fruits for salad	None	1,281,257†	1,340,547	1,256,492
Fruit cocktail	None	1,000,000†	1,681,969	3,221,353
Figs	No data	124,397	211,316	406,104
Vegetables:				
Asparagus	1,500,000	2,134,943	2,238,400	2,072,590
String beans	No data	102,067	226,915	586,563
Peas	223,923	101,098	387,974	281,884
Spinach	1,383,831	1,666,162	2,386,929	2,197,750
Tomatoes	2,924,909	1,886,505	3,070,765	3,045,355
Tomato juice	None	348,094	1,153,064	2,317,206
Tomato paste	No data	244,830	810,107	1,516,787

* For the year 1936.
† Estimated.

Dixon's line. Transportation rates from the fruit-growing districts of the Pacific coast to this region are high, and fruit canned on the Pacific coast cannot compete in price with fruit canned in the region mentioned. At the present time, however, fruit grown in this consuming region is not of as high quality as that canned on the Pacific coast. Ordinarily it will not pay to transport the lowest grades of fruit canned on the Pacific coast to the eastern market because normally these grades of fruit are supplied by the local canneries. On this account canneries of the Pacific coast have striven to maintain careful grading systems and to produce the maximum quantity of higher grades of canned fruits. It can be seen, therefore, that the cost of transportation and the quality of the finished product are both very important considerations.

Canned fruits are marketed either under the label of the cannery or under those of jobbers, wholesalers, or large retailers. Many canners sell practically none of their output under their own label but rely upon dealers in various parts of the United States to dispose of the goods under dealers' labels, chain store labels, and other labels. Frequently it is less difficult to dispose of the pack in this manner than to establish the cannery's own brand. The marketing of canned products under the canner's label, however, is apt to be more nearly permanent and usually

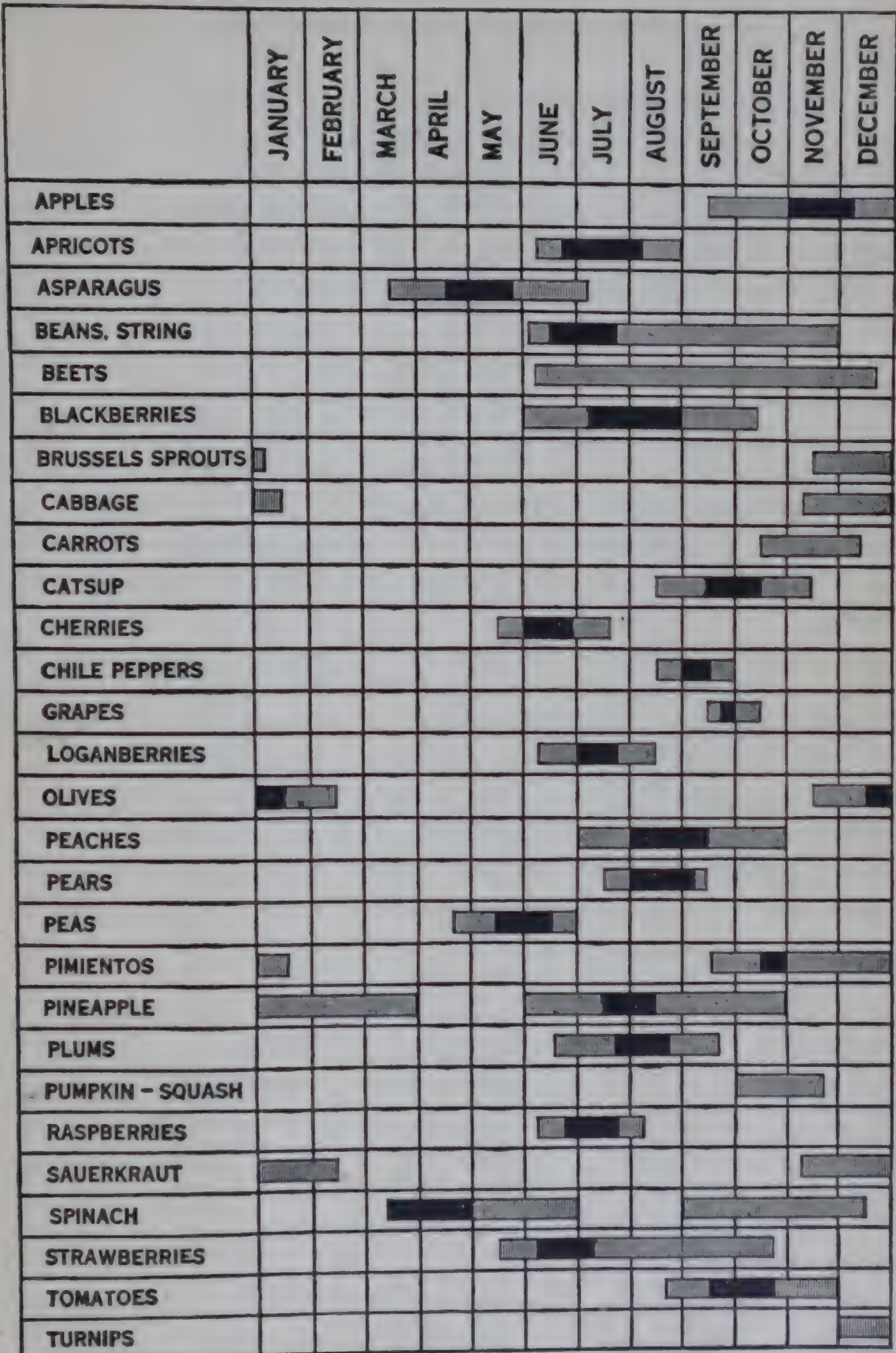

Fig. 6.—Chart showing fruit and vegetable canning seasons in California and pineapple canning season in the Hawaiian Islands. Heavy black lines represent periods of heaviest canning. (*After California Packing Corporation.*)

permits of more rapid expansion of the business after the brand has become established.

Length of Canning Season.—The overhead cost of production will be very much less per case of canned product if the canning season lasts 6 months instead of 1. It is therefore desirable to have available for canning purposes several varieties of fruits and vegetables. Tomatoes, asparagus, peas, string beans, spinach, and other vegetables are used by many fruit canneries to maintain the cannery in operation over a long season.

In California the canning season begins with the canning of spinach in March and ends with the canning of tomatoes in November or December. In that state the usual sequence of fruits for canning purposes is cherries, apricots, early peaches, pears, late peaches, and tomatoes. Very few berries are canned, but these mature during the early part of the season. In the Middle West and eastern states, canneries specialize on single crops, such as tomatoes, peas, or corn, to a greater extent than is the case in California.

Labor Supply.—Although the cannery should be located near the orchards or fields if possible, in order that the raw product will not deteriorate in quality between the time of picking and arrival at the cannery, the location of the cannery is often decided, not by the source of the raw material, but rather by the availability of labor. The average fruit cannery will require from 400 to 600 workers, ordinarily, about one-third as many men as women and girls. Some of the large fruit canneries, located in the orchard-growing districts remote from large cities, solve the labor problem by building a number of small cottages which are rented at a low rate to the families of the laborers. It is a mistake, however, to locate the cannery at such a great distance from the orchard that serious deterioration of the fruit occurs during transportation.

Transportation.—Both transportation of the raw product to the cannery and the canned product to the market must be considered.

Because of the smooth, broad highways in many states, many of the canneries now transport much of the fresh fruit by truck, which provides very rapid transportation and insures arrival of the fruit at the cannery in firm condition.

If fruit is packed into railroad cars during the heat of the day it ripens rapidly, becomes very soft and may become moldy before it arrives at the cannery. Therefore, it is desirable to load the fruit in the late evening or early morning after it has cooled. Under ordinary conditions it is not economical to ship fruit for canning in refrigerator cars.

Water Supply.—Many canneries are operated upon an inefficient and unsatisfactory basis because of inadequate water supply. The usual tendency is to underestimate the amount of water required and to be

careless of its quality. Water for canning purposes should be of good drinking quality, free of any suspicion of sewage contamination and low in mineral salts. Sulfates and iron salts are especially objectionable.

The volume of water required for each ton of fruit canned will vary considerably with the method of preparation of the fruit for canning and with the variety of fruit. Lye-peeled peaches and tomatoes require very much more water than cherries or plums since very large quantities of water are needed for washing. In one typical California cannery the amount of water used per day is about 100,000 gal. for each 75 to 100 tons of fruit or tomatoes.

The water must be delivered throughout the cannery under heavy pressure because the ability of the water used in washing to remove adhering soil and other foreign material varies with the pressure.

Sanitation.—A clean plant is the first essential in producing canned foods of high quality. The large quantities of waste water, peels, and vegetable and fruit refuse from the average cannery make it necessary to consider carefully the disposal of this waste material in order that it will not become a public nuisance.

The cannery should not be located adjacent to a gas plant, garbage disposal plant, or factories that produce disagreeable odors or large quantities of smoke or soot but should be in a district which is attractive in appearance and so located that the management would not hesitate to invite visitors to inspect it. A sightly and sanitary plant has, not only great value in improving the quality of the output, but also valuable advertising features.

Superintendence.—The maintaining of high standards of quality and the efficient operation of the plant are finally determined by the ability of the cannery superintendent. He must be a man who possesses not only a large amount of technical information but one who is also able to direct the workmen to the best advantage and who has unusual mechanical ability and an abnormal amount of energy and enthusiasm.

The superintendent must have as assistants thoroughly competent foremen in the different departments. Usually the foremen are men or women who have had a number of years' experience in canning, who are thoroughly familiar with the canning operations and equipment, and who are able to direct the work of small groups of men or women.

FACTORS IN CANNERY DESIGN

There are certain important factors of cannery construction that should be investigated before the designing and building of the plant are undertaken.

Floors.—Experience has shown that most canneries for fruits and vegetables should be built on one floor rather than on several. The

single floor facilitates the work of the superintendent because it is possible for him to have the entire cannery under direct observation at all times. The use of a single floor also facilitates the installation of conveying belts and other conveying systems, thereby reducing labor cost and systematizing the handling of materials.

The floor of the cannery must be waterproof and so constructed that it may be thoroughly washed several times daily. Concrete, which is

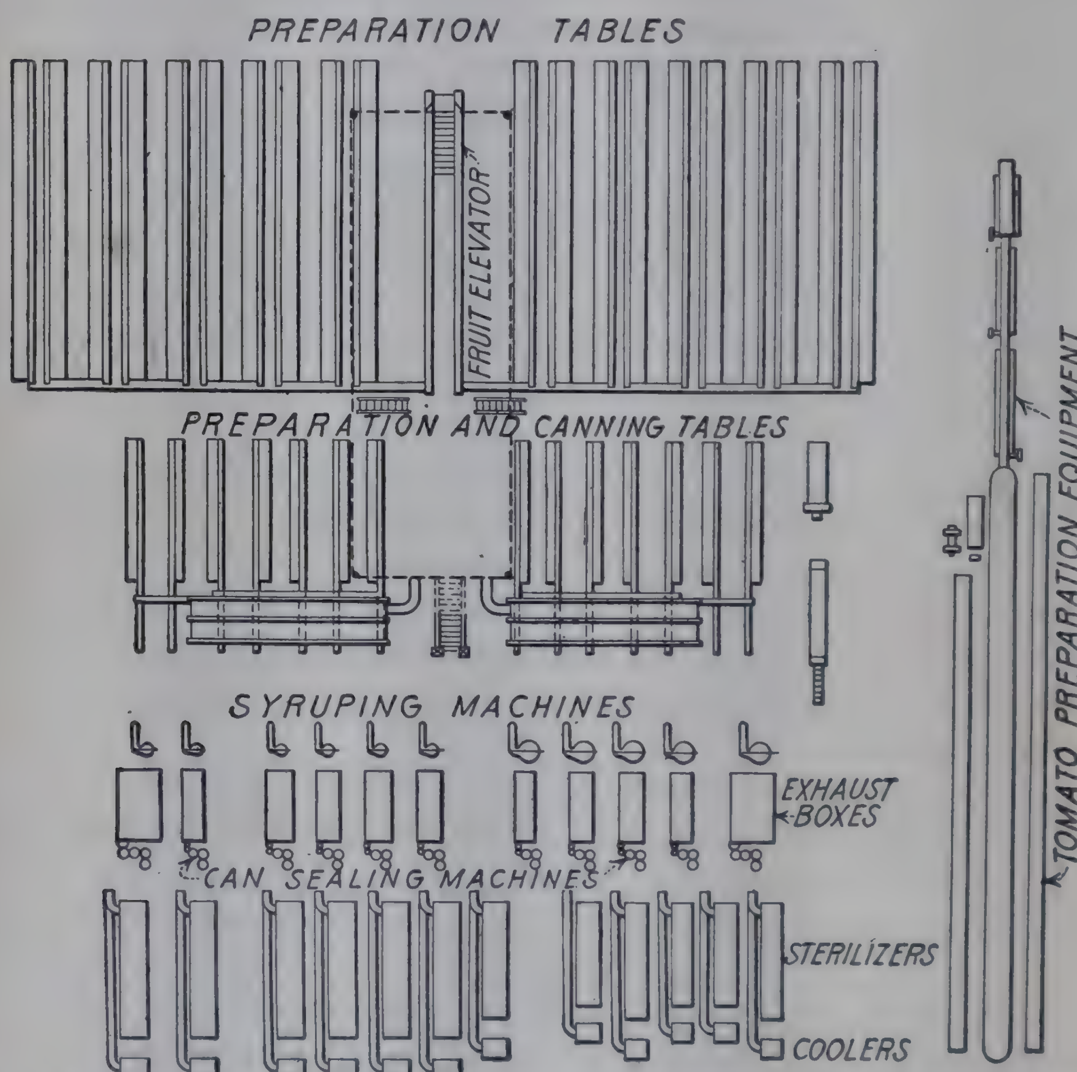

FIG. 7.—Floor plan of a typical fruit cannery in California. (*After Canning Age.*)

preferable to wood, must be laid in a single piece and not in sections, as is customary with sidewalks and similar construction, because trucking would otherwise soon cause the floor to break and disintegrate at the points of union between the various sections.

The floors should slope at about 1/4 to 1/8 in. per foot, but all parts of the floor should be within 20 ft. of a drain so that it will not be necessary for the waste water to flow too great a distance. The drains beneath the floor should be large, so that they will not become obstructed by bits of fruit and other refuse.

There is now available a special waterproof cement coating which has proved useful for surfacing cannery floors.

Ceilings and Ventilation.—The cannery roof should be high for good ventilation and so that overhead shafting will be well above the heads of the workmen. Good ventilation is particularly necessary in the processing room on account of the large amount of steam liberated during sterilizing.

In addition to providing natural ventilation in this manner, some canners have installed fans to provide artificial agitation of the air. Because the cannery floor is usually wet, the mere movement of the air across the floor causes the air to cool through rapid evaporation of moisture.

Light.—The cannery can be more efficiently maintained in a clean and sanitary condition if the interior is well lighted. It is now customary to construct the walls and a large portion of the roof of glass. This so-called "daylight construction" floods the cannery with light throughout the daylight hours, a condition which materially improves conditions for the employees, increases the output per person, and raises the quality of the work.

The painting of the interior of the cannery with a washable variety of white paint increases the light and at the same time makes it possible to detect dirt easily.

It is frequently necessary to operate the cannery at night, and therefore it should be well supplied with powerful artificial lights.

Conveyers.—The installation of conveyers reduces the labor cost of canning and makes the handling of the raw material more prompt and systematic. It is customary to transport the empty cans from the railroad cars to the cannery by special chain conveyers. It is usually possible to install conveying systems to move the peeled or cut fruit from the preparation tables to the canning tables; of canned fruit from the canning tables to the syruping machines; from the syruping machines to the exhaust boxes; and from the exhaust boxes to the can sealers and sterilizers. In some canneries the trucking of the fruit after it has been delivered to the preparation tables is eliminated by the use of suitable conveyers.

Safety Devices.—Most states compel factory owners and operators to install protective coverings for machines that are apt to injure the operators. In cases where this is not compelled by law, the cannery, as a matter of self-protection and to permit the operation of the machines without fear of injury to the workmen, should of its own accord install safety devices.

Steam Supply.—Large amounts of steam are required for sterilizing the canned product, for furnishing hot water and steam used in the prep-

aration of the raw materials, and for sterilizing the machinery. The operation of many canneries is hampered by an inadequate steam supply. A plant which is handling 100 tons of fruit per day should have a steam supply of at least 500 hp. It is desirable to have several boilers rather than a single one, in order that cleaning of one of the boilers may be possible during the operation of the plant.

Box-washing Equipment.—Fruit is generally shipped to the cannery in 50-lb. lug boxes. Even with the utmost care many of these boxes will become badly contaminated with pieces of crushed and moldy fruit or tomatoes and with fermented juices. This decomposed material will cause excessive spoilage of fresh fruit which is subsequently placed in these boxes, unless the boxes are thoroughly washed and dried before they are returned to the grower. A number of canneries in California have installed special box-washing machines to insure that the boxes are returned to the grower in sanitary condition.

Departments.—Canning operations may be naturally divided into three general steps, *viz.*, receiving, preparing for the can, and processing.

The fruit enters the cannery through the receiving room, which should be large and conveniently situated with respect to the railroad and truck unloading platforms. It should be separated by a wall or by considerable distance from the cookroom of the cannery so that it will not become heated with steam from the sterilizing room. It is usually adjacent to, and part of, the preparation room.

Between the receiving room and the sterilizing room is the preparation room, which should be separated from the other two major divisions of the cannery. This room must be equipped with washable floors and with an abundant supply of water for washing floors and equipment. In the preparation room the fruit is peeled, cored, graded for size, filled into cans, and mixed with syrup of the proper concentration. Vegetables are cut, husked, blanched, or otherwise prepared and filled into cans.

The sterilization room which is often very humid from the escape of steam and considerably warmer than the other rooms in the cannery, should be as completely separated from the preparation room as possible. The exhausting and sterilizing processes take place in this room.

In addition to these three major divisions of the cannery there is a syrup or brine preparation room, which is usually placed above the fruit preparation room. It must be well screened against the entrance of flies or other insects and must be maintained in a very sanitary condition.

The warehouse is usually a separate building, located at some distance from the cannery proper, so that the cans will not be heated or caused to rust by escaping steam from the sterilizing room.

The power plant is also usually in a separate building.

The various departments should be in charge of competent foremen who are all under the direct supervision of a general superintendent. Where responsibility is localized in this manner it is possible to develop efficient operation of the plant.

Cold Storage.—During the rush of the fruit season the cannery may be oversupplied with fruit or vegetables, and raw material sufficient for 5 or 6 days' operation of the cannery may arrive in a single day. Much of this raw material will spoil unless cold-storage facilities are available. Some canneries in the past have utilized local commercial cold-storage facilities as much as possible but have found this somewhat costly and troublesome because of the transportation of the raw product to and from the cold-storage plant. In order to avoid this inconvenience and to provide ample cold-storage space when needed, several of the canneries of the Pacific coast have installed cold-storage plants, which have proved to be very valuable adjuncts to the cannery.

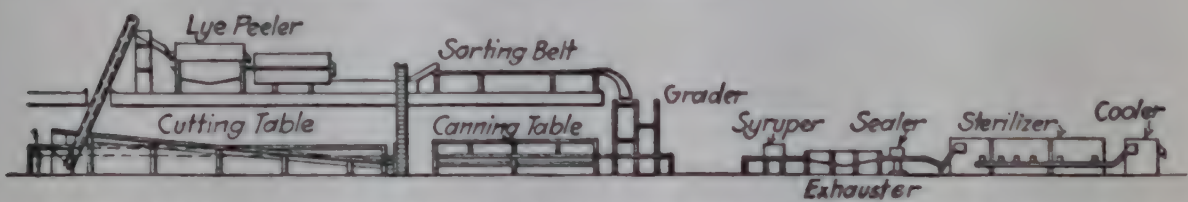

FIG. 8.—Sketch of section of typical California fruit cannery. (*After Canning Age.*)

A notable example of a successful cannery-owned cold-storage plant is found at the Eugene Fruit Growers' Association's cannery at Eugene, Ore. The ice plant is used for the manufacture of ice cream and ice in addition to its use during the fruit season for the storage of cherries, peaches, and other perishable fruits.

Machinery.—Cannery equipment should be of the best design and construction, and only standard and efficient machinery should be purchased and installed. Some sterilizing machines require a much larger amount of steam than other more modern types of sterilizers. Some recent can-sealing machines are much superior to some of the older types still on the market, and the same may be said of most of the machinery used in the cannery.

New inventions and improvements in canning machinery have been numerous in the last few years, and it will be necessary for the builder to study them very carefully. It will pay him in all cases to visit canneries in operation and to discuss with managers and superintendents the merits and defects of the various machines before he places his orders.

CANNERY ORGANIZATION

Canneries are always operated at high pressure during the rush of the canning season, and unless the work is systematized and the superin-

tendent has under his direction efficient foremen in the various departments, the cannery will soon be in chaos, or its operation become so inefficient that all possibility of profitable operation is lost. It is necessary to study the operation of the plant very carefully and to plan the work well in advance of the canning season.

The Field Department.—The cannery must have in its service men thoroughly familiar with the growing and picking of fruits and vegetables for canning purposes. In addition they must be able to deal tactfully, yet forcefully when necessary, with the grower so that fruit and vegetables of the best quality shall be taken to the factory and that the products arrive at the cannery when needed. It is one of their duties to see that the cannery has sufficient raw products to operate at full capacity without danger of an undue oversupply.

Receiving Department.—The foreman of the receiving department must be thoroughly familiar with fruit varieties, in order that fruit may be segregated according to variety on its arrival at the cannery. He must also be familiar with the different grades of canned fruit and vegetables in order that a rough grading for quality can be made in the receiving room. He must deal directly with the grower and decide whether the raw product delivered is of high enough quality to be used by his cannery. It will be necessary for him to sample loads of fruits or tomatoes and determine their value for canning purposes. In some canneries the fruit is graded into first, second, and third quality, in other cases into two grades only. The grower is paid accordingly.

For example, first-grade fruit was accepted in one cannery at $35 per ton, and second-grade fruit at $15 per ton. The foreman of the receiving department must be fair in his dealings with the grower and not take unfair advantage, if the confidence and patronage of the growers are to be retained.

Preparation Department.—In most canneries the preparation department is under the direct supervision of the cannery superintendent, but he is always assisted by a number of foremen and "foreladies," individuals who are thoroughly familiar with the processes employed in the preparation of the raw product and who are at the same time capable of directing the work of the cutters, peelers, and other workers. Most of the work in this department is done by women, and women have proved most successful as "foreladies."

Sterilizing Department.—The sterilization of the canned product is the most important in the canning process. The time and temperature of sterilizing will vary with the maturity of the fruit and other conditions. The operation of the sterilizers must, therefore, be directed by a man who is thoroughly experienced in the sterilization of fruits and vegetables and who is qualified to adapt the time and temperature to the needs of the

product. Oversterilization will result in softening and deterioration of fruit and most vegetables and understerilization will result in excessive spoilage. The foreman in the sterilizing room has the greatest responsibility of any individual foreman in the cannery. In California the operators of retorts (autoclaves) for nonacid foods must be licensed by the state.

Syruping Department.—The preparation of syrup and brine for fruit and vegetables requires great care and a thorough knowledge of the relative quality of the different grades of sugar and salt used in canning operations. Only experienced and careful workmen should have charge of this important operation.

Sales Department.—Many canneries fail because they have not developed profitable markets for their canned products. A well-organized and thoroughly competent sales organization is therefore necessary.

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CHAPTER VI

WASHING, BLANCHING, AND PEELING FRUITS AND VEGETABLES

Washing, blanching, and peeling fruits and vegetables for canning may be conveniently considered together, since in many instances these operations are conducted simultaneously.

WASHING FRUITS AND VEGETABLES

Water is used for five purposes in the cannery, *viz.:* (1) for the generation of the steam used in sterilizing; (2) for lye peeling, washing, and other preliminary treatment of the raw materials; (3) for the preparation of brine and syrup; (4) for washing the floors, machinery, and cans; and (5) for cooling the canned product.

Soaking.—Fruits or vegetables may be washed with water in three different ways, *viz.*, soaking, washing by agitation, and sprays. Soaking in itself is not an effective means of removing dirt but is useful as a preliminary treatment to washing by sprays or by agitation. It is especially desirable for tomatoes because it softens the sticky coating and renders washing by sprays more effective.

Hot water is a more effective soaking agent than cold water. It is essential that the water be abundant and changed frequently; otherwise, the soaking vat may serve as a source of contamination rather than as a means of cleansing.

Washing by Agitating in Water.—If the fruits or vegetables are agitated in water, the efficiency of the soaking process is greatly enhanced. A very simple form of agitating washer is that used in some factories for the washing of apples for cider manufacture, the apples being conveyed through a current of rapidly running water in a wooden flume.

Compressed air is sometimes used to agitate water in tanks in which the fruit or vegetables are to be washed, as in one method of washing spinach, or it may also be agitated or circulated by means of a pump. In some cases the soaking vat is equipped with a propeller, which may be in contact with the product, in which case the propeller should move slowly to avoid bruising; or it may be inclosed in a small heavily screened cage at one side of the tank.

The rotary washer used in the lye peeling of peaches is very effective. This consists of a rotary drum or a series of several drums, each of which is equipped with an inner helical conveyer. The drums rotate in tanks of

water in which the water is changed continuously or frequently. The spiral carries the fruit progressively through the different washing tanks, the first of which is contaminated with a small amount of lye from the lye-peeling tank while the last two tanks are filled with hot and cold water, respectively. This washing device is also used in lye dipping and rinsing of prunes for drying. It has great capacity, does not bruise the fruit badly, and is economical of water. It is not, however, so effective or economical of water as the spray system.

Washing by Sprays.—Washing of fruit and vegetables by means of sprays of water is by far the most satisfactory method. Products that are heavily contaminated with soil or other objectionable material

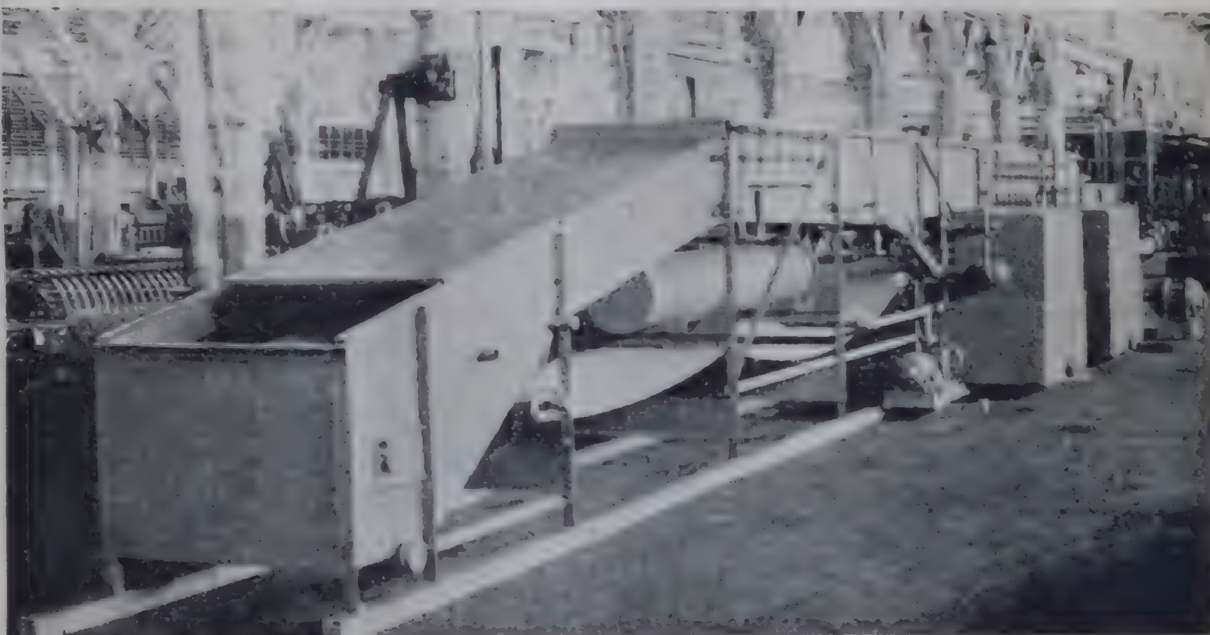

FIG. 9.—Spray-type lye peeler (Dunkley). (*Courtesy Food Machinery Corporation.*)

should first be soaked thoroughly to loosen adhering soil before washing under sprays.

The efficiency of a spray of water for washing depends upon the pressure of the water, upon its volume and also upon the distance of the spray nozzle from the product to be washed. The spray in which a small volume of water under heavy pressure is used is very much more effective than the one in which a large volume of water under low pressure is employed.

The distance of the nozzle from the product to be washed very greatly affects the efficiency of the spray. Too little attention has been given to this very important detail in some spray washing machines.

Most spray washers consist of pipes that are fitted with hack-sawed openings, but for pressures of water in excess of 20 lb. to the square inch, it is advisable that adjustable nozzles be used to prevent unevenness and to direct the sprays in the desired channels. The sprays are effective

only if the water touches all parts of the surface of the product. One means of attaining this object is to place sprays above and below a traveling, woven wire-cloth conveyer. The same effect can be obtained by causing the product to roll during the spraying process. The most effective means of agitating the product under the spray is the revolving spray washing machine used on tomatoes and roots. This consists of a slightly inclined perforated drum fitted on the inside with helical spirals or with corrugations. This type of washer is also used effectively in the washing of spinach.

The effectiveness of the rotary washer depends upon the speed with which the product passes through the washer, upon the volume of water used, upon the temperature of the water, upon the distance of the sprays from the product, and upon the depth of the product in the washer. Many washers are overloaded with such products as tomatoes, with the result that much of the material does not receive the full force of the sprays.

SCALDING AND BLANCHING

Most vegetables are heated in water or in live steam before canning, this treatment being known among canners as blanching. It cleanses the product; decreases its volume so that a well-filled can is obtained; in some cases it removes disagreeable odors or flavors; and with some vegetables it removes slime-forming substances. It may or may not aid in retention of the green color of the vegetables, depending upon the vegetable and the temperature used in blanching.

The procedure and equipment will vary with the vegetable. At present spinach is passed by conveyer through a long, covered metal tank containing water held at about 170°F. by means of automatic temperature regulators that control steam jets. This procedure is known as the Thomas process and is operated under the Thomas patent at present held by the California Packing Corporation. At the boiling point blanching of spinach results in loss of the green color, *i.e.*, in decomposition of the chlorophyll to phaeophytin of a yellowish-green color. Blanched at 170°F., it retains its natural green color to a remarkable extent, even when heated to 250°F. during subsequent sterilization. Why the lower temperature fixes the color has been a mystery. One hypothesis has been that oxygen in the leaves oxidizes the chlorophyll at the boiling point and does not do so at 170°F.; the gas also being given an opportunity at the lower temperature to escape from the tissues so that oxidation does not occur during subsequent sterilization. In experiments conducted by the writer in 1924, it was found that subjecting spinach leaves to a high vacuum for several minutes under water—to remove gases from the tissues—greatly improved the color attained in blanching. Another hypothesis

is that blanching at the lower temperature leaches considerable acid from the vegetable so that there is less hydrolysis of the chlorophyll to phaeophytin during subsequent sterilization. The fact that spinach leaves or other green vegetable impregnated with dilute sodium bicarbonate or buffered to neutrality or faint alkalinity in other ways retain their green color remarkably well is a point in favor of the "phaeophytin" hypothesis. Another theory is that at the lower temperature the enzyme chlorophyllase remains active for a few minutes and converts chlorophyll to a phyllin which retains a green color. One objection to the blanching of spinach at 170°F. is the greater difficulty encountered in filling the can so that it will contain the minimum legal drained weight after sterilizing.

Peas and string beans are carried through hot water, usually boiling, during blanching. The severity of blanching should be regulated according to the maturity and tenderness of the vegetable by varying the length of the blanching period or the temperature of the water. Hard water that is high in calcium or magnesium salts will cause hardening and toughening of peas blanched in it, probably owing to reaction with pectic substances. Asparagus is usually placed in rattan baskets that are conveyed through long vats of water at, or slightly below, boiling, although at least one California cannery has used a blanching temperature very much below the boiling point.

In blanching green vegetables for freezing storage, it was found by H. C. Diehl of the U. S. Department of Agriculture that it is necessary to heat sufficiently to destroy the catalase enzyme in order that the frozen vegetables will not develop a hay-like odor and flavor in storage. Joslyn and Marsh of the Fruit Products Laboratory of the University of California have shown that a temperature of blanching well below the boiling point gives a frozen product of better texture and flavor than does boiling. Unblanched green vegetables develop a grayish-green color as well as disagreeable odor and flavor during storage.

Corn is not blanched on the cob, but it is given a precook in sweetened brine before canning. Pumpkin is cooked in the shell until soft, the pumpkin being cut in large pieces before cooking. The object is to permit separation of the flesh and shell mechanically before canning.

Tomatoes are blanched in steam or boiling water a short time to crack and loosen the skins. Sweet potatoes and beets are usually heated in steam or in steam under pressure in order to facilitate peeling.

Pimentos are usually roasted in a gas flame or red hot metal drum, instead of being blanched in water or steam, as very severe heat treatment is required in order to loosen the skins.

Peaches are often blanched after lye peeling in order to remove the last traces of lye and to inactivate the oxidase responsible for blanching. Other common canning fruits are not blanched.

In preparing prunes for drying they are dipped about 30 sec. in dilute lye solution (0.5 to 1.5 per cent sodium hydroxide) to crack the skins and thus facilitate drying. Some Thompson seedless grapes are treated in similar fashion.

Magoon and Culpepper concluded from their investigation on blanching that steam is preferable to boiling water as a blanching agent as it extracts less of the valuable food materials. Others have found that the water-soluble vitamins B, C, and G are leached from the vegetables during blanching in water. However, steaming destroys most of the green color in spinach, *i.e.*, it so affects it that it bleaches to a yellowish green during sterilization in the can.

The subject of blanching is a very important one, as well as one that is imperfectly understood and in need of much research.

THE PEELING OF FRUITS AND VEGETABLES FOR CANNING

The quality of certain canned fruits and vegetables depends in large measure upon the care taken in peeling.

Hand Peeling.—During the first years of the fruit canning industry in California, peaches were peeled by hand. At the present time commercial canners do not peel the fruit in this manner but use instead the lye-peeling system.

The knife formerly used for the hand peeling of peaches has a curved blade with an adjustable guide, which permits regulation of the depth of peeling.[1] The objection to the hand peeling of peaches is that it is very much more costly than lye peeling and is more wasteful of fruit. The hand peeling of vegetables of certain varieties is used in conjunction with various other preliminary treatments which are discussed below.

Pears for canning were until recently peeled by hand by the knife described above, and at the same time the fruit is cut in half and the stems, calyxes, and cores are removed. Apricots are halved and pitted by hand. Satisfactory mechanical peelers are now available for pears. Peaches are pitted and halved by hand in some canneries; in others recently perfected, automatic pitting machines are used.

Use of Heat in the Peeling of Fruits and Vegetables.—Some varieties of peaches may be peeled by placing the halved fruit on trays in a steam box for 2 or 3 min. or by immersing the halved fruit in boiling water for a short time. This treatment loosens the skins so that they may be easily slipped from the fruit with the hands.

Tomatoes are blanched in steam or in boiling water, and then immersed or sprayed with cold water to cool the fruit and to loosen the skins. After blanching and cooling, the tomatoes are easily peeled by hand. Boiling

[1] Peeling and cutting knives are illustrated in Cruess and Christie's "A Laboratory Manual of Fruit and Vegetable Products."

water is probably more desirable than steam as a blanching agent for tomatoes for the reason that it heats them uniformly and cleanses them in addition to loosening the skins. The time for immersion in boiling water is approximately 30 to 60 sec.

Sweet potatoes are steamed under pressure to soften the skin and are then peeled by hand or are lye-peeled.

Beets are blanched in boiling water or in steam until the skin may be separated from the flesh easily. The blanched or parboiled beets are peeled by hand.

Pimentos are canned in large quantities in southern California and Georgia. Three different methods of peeling are in use. In one process

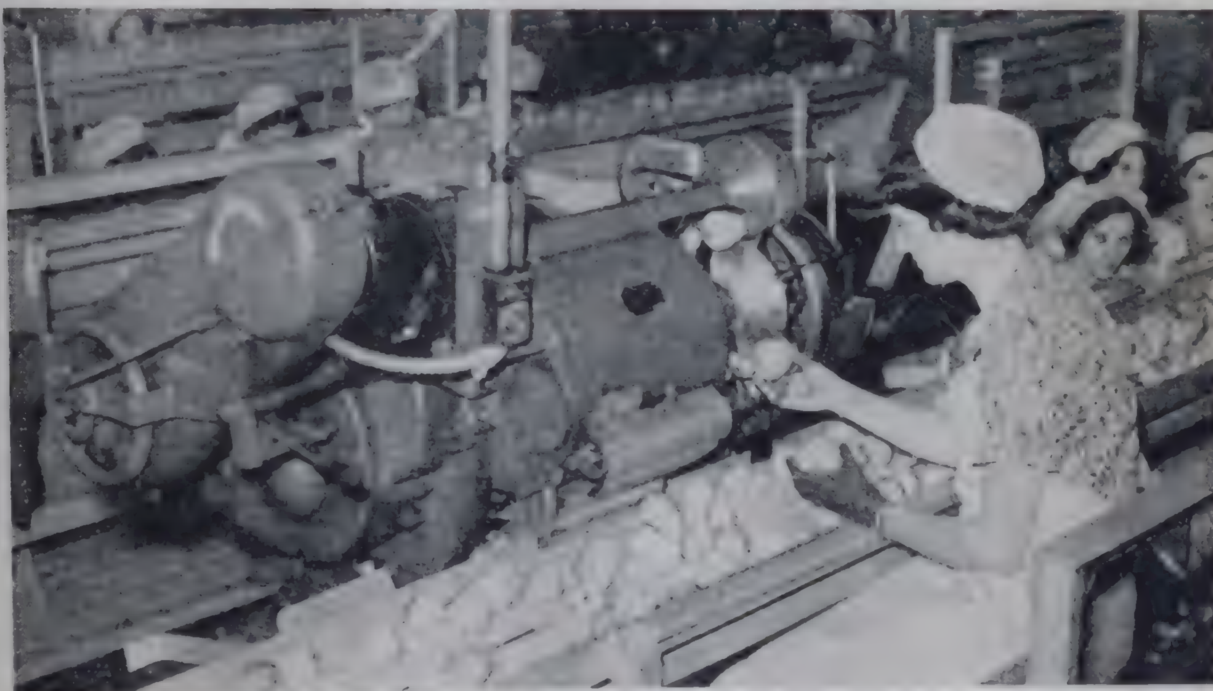

Fig. 10.—Pear-peeling -coring and -trimming machine. (*Courtesy Food Machinery Corporation.*)

the pimentos are passed through a revolving steel cylinder which is heated by a direct gas flame. The pimentos are roasted, and the peels may be easily removed from the roasted product by hand or heavy sprays.

The second process consists in passing the pimentos through a bath of cottonseed oil at about 400°F. This accomplishes the same purpose as the roasting process.

The third process of peeling pimentos is with a dilute boiling lye solution in the same manner as described for the lye peeling of peaches. This is the least satisfactory method and is now seldom used.

Mechanical Peeling.—Apples are peeled in machines that remove the peeling, core the fruit, and if desired, cut it in circular slices.

Root vegetables, such as carrots, turnips, parsnips, etc., are peeled in a mechanical peeler consisting of an upright cylinder provided in the bottom

with a rapidly revolving disk, which in addition to its rotary motion undergoes an undulatory movement. The inner walls of the cylinder and the upper surface of the disk are coated with an abrasive material, such as carborundum. As the disk revolves, water is sprayed into the peeler, washing away the grated peelings and facilitating the peeling process. Pears are now peeled and cored by machine (see Fig. 10).

Lye Peeling.—Lye peeling was probably first used commercially in the production of hominy, when the corn was peeled with lye consisting of the leachings from wood ashes. Corn was boiled in this dilute lye solution until the skins could be slipped from the kernels with the fingers, and the skins removed by washing the lye-treated corn in running water. At the present time hominy is made by boiling corn in dilute sodium hydroxide solution, followed by removal of the skins in revolving cylinders and running water. Usually a small amount of sodium hydroxide remains in the finished product. Lye peeling is used on peaches, sweet potatoes, apricots, and carrots.

The application of lye peeling to the preparation of fruits for canning is more recent. The first patent granted for the lye treatment of fruits was in 1901 for a process of dipping prunes in lye to facilitate drying. In this case the lye treatment is not prolonged sufficiently to peel the fruit but merely to check the skins.

The first patent for the lye peeling of peaches and other fruits was granted in 1902. Experiments by M. E. Jaffa, of the University of California, and others have proved that lye-peeled fruit contains no free alkali, because the small amount of lye remaining in the fruit after washing is neutralized by the acidity of the fruit.

Advantages.—The advantages of lye peeling as compared to the hand peeling of peaches are: (1) It reduces the cost of peeling; (2) it permits more rapid handling of the fruit; and (3) it causes less loss of fruit by peeling.

Action of Lye.—A boiling dilute lye solution causes the separation of the outer skin of the peach from the flesh beneath the epidermal layer, which is insoluble in the dilute lye. The middle lamella of cells consists of pectinous substances which are very soluble in the lye. The parenchyma cells of the peach are large and more resistant to the lye than the cells immediately beneath the epidermis. The vascular bundles throughout the tissues of the fruit are resistant to the lye solution. If the lye-peeling process is carried out satisfactorily, the pectinous substances of the middle lamella of cells beneath the skin will be dissolved and the parenchyma cells will be uninjured. If the lye solution is applied for too long a time or is too concentrated, the surface of the lye-peeled peach will be rough and pitted because of the action of the lye on the flesh.

In the lye peeling of sweet potatoes the action of the lye is upon the cutin. The epidermis of the sweet potato is made up of cork cells which

are insoluble in the lye solution. Because of the resistance of the epidermis the lye treatment is applied for a longer time than in the peeling of peaches, *e.g.*, 6 to 8 min. as compared with ½ to 2 min. for peaches.

Forms of Lye Used for Peeling.—Sodium hydroxide is the most common lye used in the peeling of fruits. A mixture of sodium carbonate and sodium hydroxide may also be used, although the action of the carbonate is much less vigorous than the action of the hydroxide. However, the presence of the carbonate makes it much less difficult to wash the lye from the fruit. The sodium carbonate-sodium hydroxide mixture is sold as "Canners' Alkali."

The most convenient forms of the sodium hydroxide are the granular and the flake, either of which should contain at least 95 per cent sodium hydroxide. The manufacturers of sodium hydroxide report its strength to the canner as "per cent sodium oxide" (Na_2O). The relation between "per cent Na_2O" and per cent NaOH (sodium hydroxide) is shown in the accompanying table.

It is unfortunate that this system of reporting the strength of canners' lye has come into commercial usage for the reason that sodium hydroxide and not sodium oxide is the active agent.

Lye-peeling Machines.—Several forms of lye-peeling machines are in commercial use. The Dunkley lye peeler consists of a long elevated, rectangular sheet-metal box through which a wide, endless woven-wire conveyer carries the halved peaches or other raw material. As the product enters the peeler, it is subject to sprays of hot water. The fruit then passes through sprays of hot lye solution applied to it from beneath and above the screen. While the fruit is not agitated, all portions of the surface are thoroughly acted upon by the hot lye solution. The lye and hot water are held in tanks beneath the peeling chamber and are circulated by means of pumps. After passing through the lye sprays, the fruit is subjected to sprays of water. The water used in the first set of sprays is circulated by means of a pump and is used repeatedly, but the final washing of the fruit, is done by sprays of fresh cold water.

Table 4.—Relation of Sodium Oxide to Sodium Hydroxide Content of Commercial Sodium Hydroxide

Per Cent Sodium Hydroxide, NaOH	Per Cent Sodium Oxide, Na_2O
50	38.75
60	46.50
70	54.25
75	58.12
80	62.00
85	65.87
90	69.75
95	73.62
98	75.95
100	77.50

The Kyle peeling machines make use of agitation of the lye-treated fruit in water as a means of removing the lye and skins. A revolving drum first carries the halved peaches through a tank of boiling dilute lye solution and then through a tank of running water. In recent years, however, the tank of water has been replaced with, or is followed by, sprays of water in some plants, as apparently the Dunkley patent on the use of sprays has expired.

In most canneries after washing, the lye-peeled fruit is passed through a tank of hot water (at 140 to 180°F.) to remove the last traces of lye and supposedly to inactivate the oxidase in the surface of the fruit. Oxidase is an enzyme that induces browning of the peach flesh and as shown by Quin and Cruess is inactivated in peach tissue at about 180°F. Therefore, heating at 140°F. affects it but little, and the principal beneficial effect of water at the lower temperature is removal of traces of lye. Quin and Cruess found that browning of lye-peeled peaches, between the time of peeling and placing the fruit in the cans, can be completely prevented by immersing the peeled fruit in dilute hydrochloric acid for a few seconds. The inhibiting action of this acid is due to both the hydrogen ion and the chlorine ion. The trace of acid is removed later at the canning table by rinsing in water. The hydrochloric acid forms harmless sodium chloride (ordinary salt) with the traces of residual lye on the fruit and inactivates the oxidase. Citric acid solution, about 0.5 per cent, can be used instead of the hydrochloric but is not quite so effective. It was found in these experiments that the natural pH value of the flesh of canning peaches is usually 3.8 to 4.0, whereas that in the pit cavities ("cups") of the lye-peeled peaches after washing is often above pH 7.0 (slightly alkaline) and of the outer surface of the peach often above pH 4.5. At these relatively high pH values darkening is extremely rapid, as oxidase action is favored by low acidity or slight alkalinity. For this reason Quin and Cruess recommend that the fruit be given a dilute acid bath or spray following washing after lye peeling, in cases where browning is serious. This problem will be discussed further in Chap. XI.

Concentration of Lye Solution.—The usual concentration of the lye solution is from 1.5 to 2 per cent sodium hydroxide, but it may be stronger for green fruit and somewhat weaker for ripe fruit of varieties that are easily lye peeled. It is varied materially according to variety and maturity. The temperature should be maintained at, or within a few degrees of, the boiling point. Heating the fruit in hot water or steam before it enters the lye solution greatly improves the peeling action of the lye. This is usually done in the Dunkley peeler.

In most canneries no attempt is made to control the concentration by chemical analysis of the peeling solution, although in a number of others samples of the solution from the peeling tank are titrated frequently with

standard acid solution, and the solution adjusted as required. The fruit rather rapidly neutralizes the lye and much of the solution is carried out of the vat mechanically by the fruit. Water must be added to maintain the volume constant. Automatic control devices dependent on conductivity of the liquid are also in use (see page 411).

The concentration of the peeling solution can be determined also quickly and accurately by means of an electrical conductivity instrument, constructed for use with ordinary 110- or 220-volt alternating current. There are also indicating conductivity instruments that can be attached to simple iron electrodes, such as those of a spark plug, inserted in the boiling lye solution. The instrument can be calibrated by titration of several lye solutions. The operator can then at all times determine at a glance the concentration of the lye solution in the peeling tank. Fortunately, the hydroxide ion is a very much better conductor than the negative ions of organic acids; thus the conductivity is but little affected by salts of sodium formed by neutralization of the lye by acids of the fruit.

In some canneries strong, or in some cases saturated, lye solution is added to the lye-peeling solution to maintain the desired concentration; in others flake hydroxide is added directly. Some canners use the solid, fused NaOH in steel drums, as follows. The drum is placed on end above the tank and steam is admitted through a hole in the bottom of the drum. The condensed hot water formed slowly dissolves the "caustic" (NaOH), and the saturated solution trickles in a small stream into the tank.

All operators watch the appearance of the peeled fruit closely. If they see that peeling is incomplete, the lye concentration is increased, and if it is penetrating too deeply, it may be diluted. Careful control of the lye concentration will not only save lye but also prevent excessive loss in weight and undue decrease in size of the halves during peeling.

Length of Immersion in Lye.—In California the length of immersion varies from about ½ to about 1½ min. The time of immersion or the concentration of the lye solution can be varied to suit the condition of the fruit. The output of the peeler is affected, of course, by varying the time of immersion, therefore usually the lye concentration rather than the time is adjusted.

Amount of Lye Used.—The amount of lye used per ton of fruit varies greatly according to the variety, its maturity, and the style of peeling machine used. Most California canners estimate the lye consumption at 6 to 8 lb. per ton of fresh fruit. This estimate agrees well with data taken by T. Douthit of this laboratory several years ago.

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Note: See chapters on canning fruits and vegetables for further information on washing, blanching and peeling.

CHAPTER VII

GRADING FRUITS AND VEGETABLES FOR CANNING

One of the most important factors in determining the quality of canned fruits and vegetables is careful grading. It is to be regretted, however, that the labels on canned fruits and vegetables very often do not bear a statement which will indicate to the purchaser the grade of the product in the can, although dealers purchase the canned product from the canner strictly on the grade basis. However, during the past few years labels have become much more informative. In many cases the initiative has been taken by the canners and in others the improvement has been brought about by federal and state laws and regulations such as the McNary-Mapes Act and the California Canned Fruit Seconds Act.

Objects of Grading.—The grading of the fruit before canning results in greater uniformity of the finished product and in the standardization of methods of canning, sterilizing, etc., thus tending to reduce operating costs.

The advantages of grading have been recognized by practically all commercial canners, and the day when a can contained all grades and sizes of fruit or vegetables is past. It is believed that if the American housewife were thoroughly familiar with the different commercial grades, the consumption of canned products would increase.

Effect of Variety on Quality and Grades.—Some varieties of peaches, pears, cherries, and other fruits are more desirable than others for canning purposes. Therefore, in choosing fruit for canning, the proper variety for the purpose should be selected. Fruit varieties will be discussed further in Chap. XI.

Effect of Maturity.—In addition to choosing the proper variety, the canner must make certain that the product is picked at the proper stage of maturity. Fruit for canning purposes is usually gathered when *firm ripe*, *i.e.*, not quite ripe enough for table use but of full size and with considerable flavor. The term "canning ripe" is well known to the fruit grower and canner and has come to have a very definite meaning. Immature fruit is lacking in color and flavor; that which is overripe is apt to soften badly during sterilization in the can.

The quality of canned vegetables also depends to a very marked degree upon the maturity of the raw material. This is particularly true of string beans, peas, and corn. These vegetables must be gathered for canning while still tender.

Importance of Canning Promptly after Picking.—The quality of the finished product is affected very markedly by the length of time which elapses between picking and canning. On this account the raw product should be transferred from the orchard or field to the cannery in the shortest time possible.

Effect of Temperature.—The effect of temperature during shipment to the cannery is also extremely important. Railroad cars used for shipment of canning fruit should be well ventilated and as cool as possible. It is desirable to allow the fruit to stand in the orchard in open boxes during part of the night to cool before loading into cars. Fruit stored at the cannery should be placed in cold storage or in a well-ventilated room and should be held for as short a time as possible before canning.

Relation of Sanitation to Quality.—Quality is affected by sanitary conditions in the plant. Moldy boxes will often cause spoiling of fruit or tomatoes in shipment or cause them to acquire a disagreeable flavor and odor. Many of the large canneries wash the shipping boxes thoroughly in hot water or in a hot cleansing solution such as dilute lye or sodium carbonate solution in order to clean and disinfect them before returning them to the grower. Floors, canning tables, conveyers, syruping equipment, and all machinery in the cannery must be washed frequently and the premises must be kept free of decomposing cannery refuse.

Grading for Quality.—Upon its arrival at the cannery, the fruit should be graded roughly for quality. The overripe boxes of fruit should be separated from those of proper maturity. The women, employed in cutting and peeling the fruit, sort it for quality, usually after peeling or cutting, and some fruits are again sorted on broad, slowly moving belts by women who are trained for this work. A third or fourth sorting is given by the women who fill the cans with the prepared fruit. Careful sorting is essential to success in commercial canning. Vegetables must also be sorted according to maturity, freedom from blemishes, etc. Peas are graded, by flotation in brine, according to maturity. Corn must be sorted by hand according to maturity.

CANNING FRUIT GRADES ADOPTED BY THE CANNERS' LEAGUE OF CALIFORNIA

Most of the canners in California grade their fruit according to standards devised and adopted by the Canners' League of California, an organization comprising over 90 per cent of the canners of northern California. These grades are also recognized by other canners in California not members of the Canners' League. The general specifications for these grades are as follows:

Fancy grade represents fruit of superlative quality, of very high color, ripe yet not overripe, free from blemishes, very uniform in size, and very symmetrical in appearance.

Choice grade represents fruit of fine quality, of high color, ripe yet not overripe, free from blemishes, uniform in size, and symmetrical, and it is often one size smaller than the Fancy grade.

Standard grade represents fruit of good quality, reasonably good color, reasonably free from blemishes, uniform in size, reasonably uniform in color and degree of ripeness, and reasonably symmetrical.

Second grade represents fruit of second quality, tolerably free from blemishes, tolerably uniform in size, color, and ripeness, and tolerably symmetrical.

Pie or water grade represents fruit of pie quality that is wholesome fruit, not suitable to the above grades. It need not be uniform in size,

TABLE 5.—NUMBER OF PIECES PER NO. $2\frac{1}{2}$ CAN FOR VARIOUS GRADES OF CANNED FRUITS AS ADOPTED BY THE CANNERS' LEAGUE OF CALIFORNIA

Fruit	Fancy	Choice	Standard	Second	Pie
Apricots	24 or less, variation 6*	30 or less, variation 7	42 or less, variation 8	No limit	No limit
Cherries, Royal Anne	85	105	145	No limit	No limit
Cherries, other	100	125	175	No limit	No limit
Grapes, Muscat	No standard	No standard	No standard	No limit	No limit
Peaches	6–12, variation 4	6–15, variation 5	6–21, variation 6	No limit	No limit
Pears	6–12, variation 4	6–12, variation 5	6–21, variation 6	No limit	No limit
Plums	11	....	....	....	No limit

* "Variation" refers to variation in number of pieces in different cans from the same factory. Appearance of the fruit and freedom from blemishes are more important in most cases than the number of pieces per can.

TABLE 6.—BALLING DEGREE OF SYRUPS ADDED TO VARIOUS GRADES OF CANNED FRUITS AS SPECIFIED BY CANNERS' LEAGUE OF CALIFORNIA

Fruit	Fancy	Choice	Standard	Second	Pie
Apricots	55	40	25	10	0
Cherries, Royal Anne	40	30	20	10	0
Cherries, other	40	30	20	10	0
Grapes, Muscat	40	30	20	10	0
Peaches	55	40	25	10	0
Pears	40	30	20	10	0
Plums	55	40	25	10	0

maturity, color, or appearance and may contain a few blemishes. It must not contain decomposed fruit.

Table 5 gives the number of pieces of the different varieties of fruit per No. 2½ can, and Table 6 gives the concentration of syrup used for these different grades.

These may be considered as minimum standards for the five grades of California canned fruits. Many canners use syrups of higher Balling degree than those given in the table and grade their fruit according to size more rigidly than indicated in Table 5.

CHANGES IN CONCENTRATION OF SYRUP AFTER CANNING

After canning, the concentrations of sugar in the syrup and in the fruit tend to equalize. The heavy syrups, therefore, tend to decrease in Balling degree and the light syrups, if of lower sugar content than the fruit, may increase in Balling degree during storage. There is a fairly definite relation between the concentration of the syrup placed on the fruit at the time of canning and the concentration of the syrup in the fruit and can after canning and storage.

Typical Changes in Concentration of Syrups on Peaches and Pears.—According to Bitting, the following relations exist between the ordinary concentrations of sugar and the final concentration after canning and storage of peaches and pears. The concentration in a can after storage and on examination is known as the "cutout" concentration.

TABLE 7.—RELATION BETWEEN "CUTOUT" TEST AND ORDINARY CONCENTRATIONS OF SYRUP USED IN CANNING PEACHES AND PEARS, IN DEGREES BALLING
(*A. W. Bitting, U. S. Dept. Agr., Bull.* 196, p. 45)

Peaches		Pears	
Original syrup	Cutout	Original syrup	Cutout
55	26.1	40	24.1
40	22.2	30	17.9
30	18.5	20	16.6
20	16.1	10	12.9
10	12.3	0	9.3
0	9.0		

The changes in composition of the syrup are due to osmosis. In most fruits this change occurs without shriveling or without bursting of the fruit, although fruits with tough skins, such as grapes, may burst in a very dilute syrup and shrivel in a very heavy syrup.

Relation between Syrup Concentration at Canning and after Storage for California Fruits.—The figures given in Table 8 were obtained from

commercial canners and a compilation of published data, principally from *U. S. Department of Agriculture, Bulletin* 196, by Bitting, and must be considered as approximate only, because the composition of the fruit varies with the season, maturity, locality, and variety and affects the composition of the syrup accordingly (see also Tables 19 and 20).

Canned Fruits for Salad and Fruit Cocktail.—Specifications for the different grades of these two products are given in Chap. XI.

TABLE 8.—APPROXIMATE MINIMUM CONCENTRATION OF SYRUP FROM VARIOUS GRADES OF CANNED FRUIT IN DEGREES BALLING

Fruit	Fancy		Choice		Standard		Second		Pie	
	At canning	After storage	At canning	After storage	At canning	After storage	At canning	After storage	At canning	After storage
Apricots, Royal	55	27	40	21	25	17	10	12	0	9
Cherries, Black Tartarian	40	23	30	20	20	15	10	12	0	10
Cherries, Royal Anne	40	23	30	20	20	15	10	12	0	10
Grapes, Muscat	40	28	30	24	20	21	10	17	0	12
Peaches	55	26	40	20	25	15	10	12	0	9
Pears, Bartlett	40	22	30	18	20	15	10	12	0	11
Plums, Green Gage	55	27	40	21	25	17	10	12	0	9

SIZE GRADING OF FRUITS

Cherries, plums, grapes, and olives are graded for size whole, while peaches, apricots, and pears are graded after cutting in half or after halving and peeling. Pears are also in some cases graded for size mechanically before peeling or halving.

Types of Graders.—Most fruits are graded over vibrating screens with circular openings of various sizes. In most cases the thirty-second of an inch is used as the unit of measurement for these holes. The screens are usually five or six in number and are interchangeable so that one machine can be adjusted for different varieties of fruits by simply inserting the size of screen adapted to the fruit. The screens are usually made of copper, as it has been found that this metal will withstand severe use and does not injure the color of the fruit.

Screen Graders.—In some graders the large sizes of fruit are removed first. This is accomplished by allowing the smaller sizes to fall through the first screen and permitting the largest size to pass over the end of the first screen, where the fruit is conveyed to the canning tables by a belt operating at right angles to the direction of flow of the fruit. In a similar fashion the smaller grades of fruit are separated successively.

In the second style of grader the small sizes are removed first and the largest size is allowed to drop progressively from one screen to the next and finally to pass over the last screen. This is considered objectionable

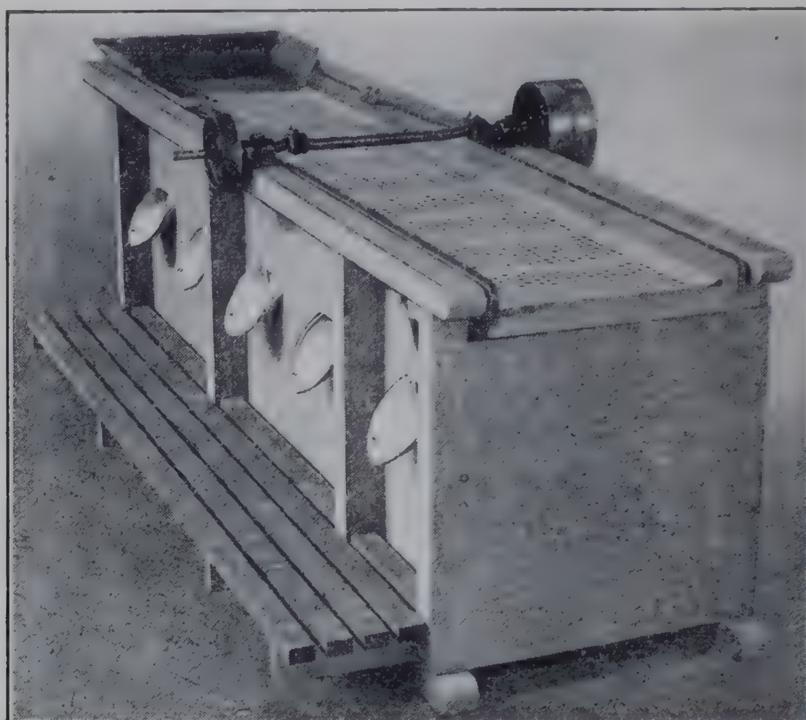

FIG. 11.—Cherry grader. (*Courtesy Anderson-Barngrover Mfg. Company.*)

because the large fruit is subjected to unnecessary agitation which may result in softening or bruising. This is particularly true of delicate-textured fruits, such as halved apricots.

FIG. 12.—Peeled-peach grader; also used for apricots, plums, and cherries. (*Courtesy Food Machinery Corporation.*)

Another form of screen grader is that used for peas. It consists of a long, revolving perforated cylinder. The perforations are circular and are of increasing size from the entrance to the exit ends.

Roller Grader.—The "roller" grader consists of two rollers, usually about 2 in. in diameter, which revolve from each other and which are closer together at the upper end than at the lower end. As the fruit passes along these rollers, the small fruit is the first to drop through and is removed. The largest sizes are removed last. This style of grader is suitable for spherical, unpeeled, uncut fruit. It has been used more or less successfully for the grading of whole peaches, apricots, and olives.

"Rope" or Cable Grader.—Olives for canning are usually graded for size by traveling, diverging, steel endless cables. The distance between the cables is adjustable.

Grading by Weight.—A well-known grader for apples and oranges grades the fruit by weight. The individual fruits fall into traveling canvas pockets placed at one end of short, counterpoised rods. The rods rest on a long iron strip which serves as a fulcrum. As the fruit is carried along the grader, the distance of the fruit from the fulcrum becomes greater. The cups tilt as the leverage of the fruit becomes greater than that of the counterpoise. The heaviest fruit is removed first and the lightest fruit last. This grader has proved popular for apples and may have possibilities for grading other fruits for canning.

Pears are graded whole by a roller grader or rubber cable grader and are also graded by hand after peeling, halving, and coring.

Diameters of Openings in Grader Screens for Common Fruits.—The usual diameters of the higher grades of canned fruits are shown in Table 9. There are no size standards for second and pie grades.

TABLE 9.—AVERAGE DIAMETER OF VARIOUS GRADES OF CANNED FRUITS (EXCEPT OLIVES)

(*After Cruess and Christie's "Laboratory Manual of Fruit and Vegetable Products"*)

Fruit	Fancy	Choice	Standard
Apricots	$^{56}/_{32}$ in.	$^{54}/_{32}$ in.	$^{50}/_{32}$ in.
Cherries, Royal Anne	$^{29}/_{32}$ in.	$^{28}/_{32}$ in.	$^{28}/_{32}$ in.
Cherries, Black	$^{26}/_{32}$ in.	$^{25}/_{32}$ in.	$^{22}/_{32}$ in.
Grapes, Muscat	$^{26}/_{32}$ in.	$^{25}/_{32}$ in.	$^{24}/_{32}$ in.
Peaches	$^{76}/_{32}$ in.	$^{64}/_{32}$ in.	$^{56}/_{32}$ in.
Plums, Green Gage	$^{56}/_{32}$ in.	$^{50}/_{32}$ in.	$^{42}/_{32}$ in.
Pears, Bartlett*	8-10 pieces	10-12 pieces	15-17 pieces

* Pieces per No. 2½ can.

Normally the sizes of the various grades of fruit are equal to or greater than the diameters given in the table.

Owing to the fact that ripe olives vary greatly in form, it is customary to grade this fruit according to the number of olives per pound as indicated in the following table.

TABLE 10.—SIZE GRADES FOR CALIFORNIA RIPE OLIVES, AS DEFINED BY THE CALIFORNIA RIPE OLIVE ASSOCIATION

Grade	Approximate diameter, inch	Number of olives per pound
Small	$\frac{9}{16}$	120–150
Medium	$\frac{10}{16}$	105–120
Large	$\frac{11}{16}$	90–105
Extra large	$\frac{12}{16}$	75–90
Mammoth	$\frac{13}{16}$	65–75
Giant	$\frac{14}{16}$	55–65
Jumbo	$\frac{15}{16}$	45–55
Colossal	$\frac{16}{16}$ or above	35–45

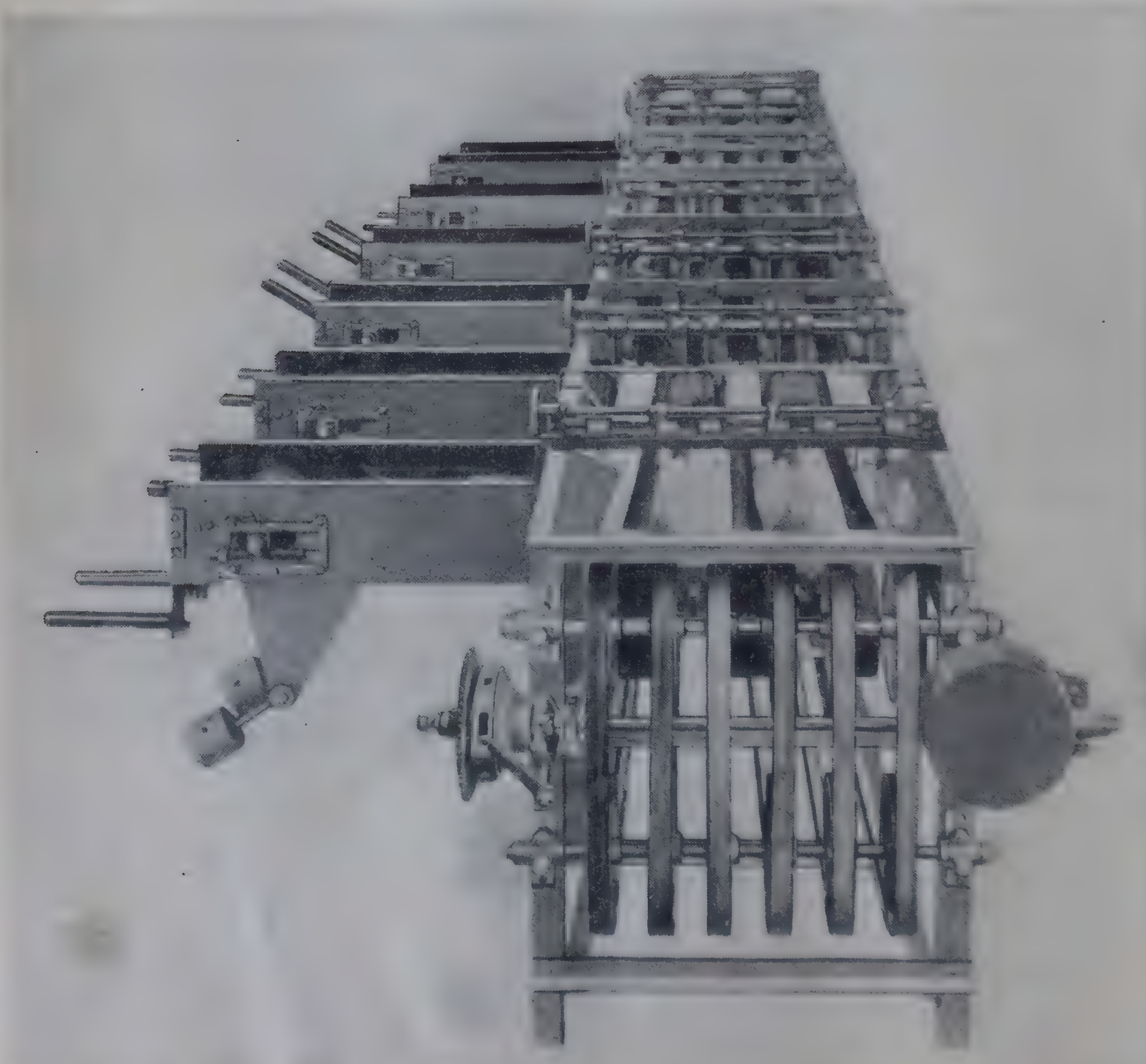

FIG. 13.—Diverging-belt grader. Useful for pears and certain other fruits. Similar types used for asparagus and olives. (*Courtesy Food Machinery Corporation.*)

Size of Grading of Vegetables.—Peas, string beans, beets, cucumbers, and asparagus are graded for size, in some cases by screens and in others by hand. The method of grading and grade designation vary with the vegetable concerned. Therefore, in order to avoid undue repetition, vegetable grading and tables of size grades will be given in the discussion of canning and pickling of the individual vegetables.

GOVERNMENT STANDARDS FOR NET DRAINED CONTENTS

The Food and Drug Administration of the U. S. Department of Agriculture has established standards for net contents of cans of certain fruits and vegetables. The investigations upon which these standards are based have been made by the various food and drug inspection laboratories of the Bureau of Chemistry.

The standards as at present established are to be considered as minimum requirements, and in most cases products canned by the usual commercial methods will readily meet or exceed these minimum standards.

The determination of the net drained weight of canned fruits and vegetables is made according to the following directions of the Bureau of Chemistry.

Draining.—For determination of drained weight the contents of No. 2½ cans and cans of smaller size should be emptied on a circular ⅛-inch mesh screen 8 inches in diameter, set in a frame with a vertical side higher than the level of the product on the screen. The contents of the can should be distributed over the screen so as to form a layer of uniform depth, this being accomplished so far as possible by the manner of emptying from the can. Such further handling as is required to level the material on the screen, in order to secure a layer of practically uniform depth, should be done in such a way as to exert no pressure, whereby additional amounts of liquor will be expressed from the material. The period of draining should be 2 minutes in all cases. The manner of determining the drained weight for No. 10 cans is the same as the foregoing, with the exception that a circular ⅛-inch mesh screen 12 inches in diameter is used. This screen should also be set in a frame with a vertical side higher than the level of the product on the screen.

Cans of sizes not mentioned should yield a drained weight of contents which bears the same relation to the drained weight indicated for the can nearest in size as that existing between the capacities of the cans in question.

In making declarations under the net weight requirement of the Federal Food and Drugs Act, the total weight of the contents of the can, liquid included, should be declared; this Bureau will regard as in violation of the Act interstate shipments of canned foods packed with lighter weights than those indicated. May 5, 1920.

Standards as at present published can be obtained on application to the Food and Drug Administration, U. S. Department of Agriculture, Washington D. C.

McNARY-MAPES ACT

This act was passed by the United States Congress on July 8, 1930. Its purpose was to protect the consumer by compelling the canner to label certain canned products of quality below Standard as Substandard. For fruits the Federal Government's Standard quality corresponds closely with the California Canners' League Standard grade. The provisions of the act are enforced by the Food and Drug Administration.

Canned fruits of Substandard quality may be labeled "Below U. S. Standard. Low quality. Good food. Not high grade." Canned vegetables provided for in the act may be labeled "Below U. S. Standard. Low quality but not illegal." The substandard foods must be edible, sound, and not decomposed. The act is a criminal statute. Violators can be prosecuted in court. Conviction carries a fine and possible dumping of the product.

Canned peaches may be taken as an example to illustrate provisions of the act. Peaches are not classified according to variety; no distinction being made between freestone and clingstone peaches. The syrup of Standard grade must be at least 14° Brix. The fruit must be normal in color and free of abnormal odors and flavors. The pieces must not be excessively trimmed. Not more than 20 per cent of the pieces in the can may show blemishes of any sort whatsoever and no single piece may show a blemish greater in area than 5 per cent of the surface of the affected piece. No piece may be less than $\frac{3}{5}$ oz. in weight. The largest piece shall not be more than 80 per cent greater in weight than the smallest piece in the can. Texture must be satisfactory; it must not be so soft that the fruit loses its shape when poured into a dish nor so hard that it will not be penetrated by a $\frac{5}{32}$-in. needle under a pressure of 300 grams. The halves must be unbroken, except that one broken half next to the lid is allowed, the assumption being that it is broken in opening the can. Not more than 1 sq. in. of peel per pound of fruit is allowed. The drained weight must equal or exceed 60 per cent of the net maximum content of the can, except that a tolerance of one piece per can is allowed to avoid overfilling.

Similar requirements have been made for cherries, pears, and apricots. The syrup for pears must be 13° Brix or greater. For details see references given at end of this chapter.

Canned peas will serve as an example of the McNary-Mapes grades for vegetables.

To be of Standard quality the peas must be tender, immature, unbroken, normally flavored, and normally colored and may be canned with or without water. There must not be more than 4 per cent by count of off-colored peas. At least 80 per cent of the peas must have the two cotyledons intact and held together by the skin. There must not be more than

one piece of foreign material of the same specific gravity as the peas per 2 oz. (thistle heads, daisy buds, etc.). Peas are considered immature if 90 per cent or more by count are sufficiently soft so that either cotyledon is crushed by a weight of less than 2 lb. (907.2 grams); or, if not more than 20 per cent of the peas sink in a brine of 1.12 specific gravity at 68°F.; or, if the alcohol insoluble matter does not exceed 23 per cent; or, if less than 25 per cent of the peas by count are swelled to such an extent as to rupture the skin sufficiently to separate the broken edges 1/16 in. or more.

UNITED STATES QUALITY GRADES FOR CANNED VEGETABLES

By virtue of authority granted by act of Congress in 1933 the Department of Agriculture promulgated grades for most canned vegetables. The requirements for the various United States grades for canned peas and tomatoes are given briefly as illustrations.

U. S. Grade A (Fancy) canned peas are prepared from fresh, young, very tender peas of the same type; are uniform in color and, unless declared to be ungraded for size, are uniform in size. They are surrounded by practically clear liquor; are practically free from skins, broken peas, and other defects; possess the typical fresh flavor of succulent, immature peas; and score not less than 90 points according to the scoring system outlined herein.

U. S. Grade B (Extra Standard or Choice) canned peas are prepared from fresh peas of the same type, which are tender; are practically uniform in color and, unless declared to be ungraded for size, are practically uniform in size. They are surrounded by a reasonably clear liquor; are reasonably free from skins, broken peas, and other defects; possess a fresh pea flavor; and score not less than 75 points and need not score more than 89 points when scored according to the scoring system outlined herein.

U. S. Grade C (Standard) peas are described in language similar to the above except that the liquor may be roily, and possess a good pea flavor. They must score more than 60 but need not score more than 74 points.

Off-grade (Grade D) peas are those that do not meet one or more of the requirements of Grade C.

The scoring scheme for peas is as follows:

1. Clearness of liquor	15
2. Absence of defects	15
3. Uniformity of size and color	10
4. Tenderness and maturity	35
5. Flavor	25
Total	100

U. S. Grade A (Fancy) canned tomatoes are select tomatoes which are whole or almost whole; are of uniformly good red color; are practically free from pieces of skin, cores, blemishes and other defects; possess the typical flavor of naturally ripened tomatoes; and score not less than 90 points according to the scoring

system outlined herein; provided that only one factor may have a rating in and not below the range of 15 to 17 points.

U. S. Grade B (Extra Standard or Choice tomatoes) are only slightly less desirable than Grade A and score at least 75 but need not score more than 89 points. Only one factor may have a rating in the range 12 to 14 points.

U. S. Grade C (Standard) tomatoes need not be whole but consist of fairly large pieces. They must score at least 60 points but need not score more than 74 points.

Off-grade tomatoes fall below the requirements for Grade C (Standard) tomatoes.

The scoring scheme for canned tomatoes is as follows:

	Points
1. Percentage of whole tomatoes	20
2. Solidity	20
3. Color	20
4. Absence of defects	20
5. Flavor	20
Total	100

Similar grades have been established for most other commercially canned vegetables. Descriptions may be had from the United States Department of Agriculture, Bureau of Agricultural Economics, Washington, D. C.

UNITED STATES QUALITY GRADES FOR CANNED FRUITS

Grades A, B, C, and D have been promulgated for canned grapefruit, and tentative United States grades have been established for peaches, pears, cherries, and most other canned fruits.

The wording is similar for the different fruits; consequently only cling peaches will be considered.

U. S. Grade A (Fancy) canned peaches are halves or slices of well ripened peaches of similar varietal characteristics; are practically uniform in color; are practically free from defects; possess a firm but tender fleshy texture; a normal peach flavor; and score not less than 90 points.

In describing U. S. Grade B (Choice) canned peaches, the word "reasonably" replaces "practically," and they must score not less than 75 points.

In describing U. S. Grade C (Standard), the word "fairly" replaces "reasonably," and the peaches must score at least 60 points. The syrup must test not less than 14° Balling.

U. S. Grade D (Seconds) is wholesome fruit that does not meet one or more requirements for Grade C.

Syrup density cutouts are not set in the standards, nevertheless Fancy fruit must be packed in syrup of 55° Balling, Choice in 40° Balling, Standard in 25° Balling, and Seconds in 10° Balling. However, if the canner uses the words "extra heavy syrup" on the label, then the cutout must be 24° Balling or above; "heavy syrup," 20 to 23.9° Balling; "medium syrup," 14 to 19.9° Balling; and "light syrup," 11 to 13.9° Balling; all at 68°F.

The scoring scheme for canned peaches is as follows:

	Points
1. Color	25
2. Uniformity of size and symmetry	20
3. Absence of defects	20
4. Character of fruit	35
Total	100

Details are given for arriving at the ratings for each of the four characteristics and can be had on application to the U. S. Department of Agriculture, Bureau of Agricultural Economics, Washington, D. C.

Fill of Container.—The same act under which grades for canned foods were or are being established also provides for fill of container. If the level of the contents of the can is more than 10 per cent below the top, measured to the underside of the lid, the can is considered slack filled; this is the general requirement. However, the maximum allowable head space for each product in each size of container commonly used for the product is also specified. For example the maximum head space for peas in No. 1 tall cans is 9.9 sixteenths of an inch; for a No. 2 can, 9.7 sixteenths; and for a No. 10 can, 13.6 sixteenths of an inch.

For fruits the requirements are similar except that, even if the product meets the maximum head-space requirement, it may be termed "slack filled" if it is evident that more fruit could have been put in the can without damage. For fruits also the weight of the fruit must not be less than 60 per cent of the weight of water to fill the can completely at 68°F. Thus if the can will hold 29.8 oz. of water, the can must have on cutout not less than 0.6 by 29.8, or 17.88 oz. of drained fruit.

If the canned product (fruit or vegetable) does not meet the minimum fill requirements, it must be labeled "Below U. S. Standard. Slack fill."

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CHAPTER VIII

SYRUPS AND BRINES USED IN CANNING

In canning, syrups are added to fruits and brines are added to vegetables to improve the flavor, fill the spaces between the pieces of canned product, and to aid in the transfer of heat during sterilization. They also fill the can more or less completely, thereby excluding air, the presence of which causes corrosion of the tin plate.

Sugars Used in Canning.—The principal sugar used in canning is sucrose, *i.e.*, cane sugar, or beet sugar. Cane and beet sugars are identical in chemical composition. In most cases commercial cane or beet sugar contains more than 99 per cent sucrose. The prejudice against beet sugar for canning and preserving has been caused probably by the fact that during the first years of the beet sugar industry the product was not always of the highest purity and sometimes contained considerable beet molasses which adversely affected the flavor of the sugar. The beet sugar produced at present is highly refined and free from objectionable flavor or odor. Many canners, as a matter of fact, use beet sugar because it is usually cheaper.

Centrifugal Sugar.—An impure grade of cane sugar, known as Central American sugar or centrifugal sugar, is often used in the canning of fruits of dark color and where the amber color of syrups made from such sugars would not be an objection. Such fruits as yellow peaches, apricots, berries, and black cherries may be canned with this sugar. It cannot be used for pears unless decolorized by bone black before use. If used for canning fruit for export the import duty on such sugar is remitted provided appropriate records are kept.

This sugar is considerably cheaper than refined sugar but varies greatly in sucrose content and may contain as little as 84 per cent sucrose, the principal impurity being molasses. The purity can be roughly judged by the color of the syrup. Such a rough estimate of the purity, however, should be checked by chemical analysis or by polarization of an average sample.

Another grade of cane sugar is the "plantation clarified," which is usually a high grade of the centrifugal sugar, often equal to the highly refined sugar in purity.

Unrefined centrifugal sugars may occasionally contain sulfur dioxide, which may form hydrogen sulfide in the cans and a black deposit of metallic sulfide.

Invert Sugar.—The principal sugar in all of these commercial sugars is sucrose, $C_{12}H_{22}O_{11}$, which on hydrolysis yields equal amounts of glucose and fructose. The hydrolyzed product is known as "invert sugar."

For some purposes cane sugar is dissolved in water, inverted with citric acid or with invertase and concentrated to a heavy syrup, used extensively in candymaking.

Glucose.—Corn sugar, or glucose, in the form of a heavy syrup, is sometimes used in the cannery for the cheap grades of canned fruits and in the manufacture of cheap jams and jellies. It is very much less sweet than cane sugar, is produced from cornstarch by hydrolysis under pressure with dilute hydrochloric acid, and possesses the chemical formula $C_6H_{12}O_6$.

FIG. 14.—Syrup room in a fruit cannery. Square tank, upper left, is used for preparing concentrated syrup and small, circular tanks for syrups diluted for addition to cans.

The crystalline product is now obtainable in very high purity and may be used in canning or preserving without declaration on the label.

Preparation of Syrups for Canning.—In most canneries the syrup preparation room is located on the floor above the fruit preparation and canning rooms and the syrups are transferred by gravity through pipes to the syruping machines. The sugar is dissolved in a small amount of water to yield a heavy syrup, usually of 60 to 65° Balling or Brix. Glass-lined, *i.e.*, enamel-lined, steel tanks have been found most satisfactory for the syrup. The tank in which the heavy syrup is prepared is fitted with a steam-heated copper coil or open steam jets, and the water and sugar are boiled together until a clear syrup is obtained. Often a steam-jacketed kettle is used for preparing the syrup. Some impurities coagulate and are removed by skimming, and the heavy syrup is further clarified by passing it through cloth before it is transferred to the diluting vats (see Fig. 14; the square tank at the left holds the concentrated syrup).

The mixing tank for the heavy syrup is located above the reservoirs or ting vats, of which there are usually four or eight. In these vats the p is diluted by mixing measured quantities of the heavy syrup with er to give the desired Brix, or Balling, degree. The grades of syrup l for the different fruits have been given in Table 7.

Testing the Syrup.—The syrup must be tested accurately before use hat the syrup in the cans will be of form composition and the cutout not be above or below the estabed standard. In large fruit canies 25,000 to 50,000 lb. of sugar per are used. If the syrups used rage 2 per cent too high in sugar tent, this will correspond to a loss 500 to 1,000 lb. of sugar per day.

FIG. 15.—Short-stemmed Balling or Brix hydrometer, cylinder and thermometer for testing syrups.

The instrument commonly used in neries for the testing of syrups is Brix, or Balling, hydrometer, which es the per cent of sugar in the syrup. is practically always necessary to ke a temperature correction, since hydrometers are usually calibrated use at 17.5 or 20°C. (63.5 or 68°F.). ch instrument used by canners ually covers only 10° Brix; thus, 10 20, 20 to 30, 30 to 40, 40 to 50, and to 60° Brix, respectively, and are aduated in 1/10° divisions. The canr should buy only the best hydromers, since accuracy is of great portance. It is well to have for erence purposes a set of hydrometers sted and certified by the U. S. Bureau of Standards or other similar ency.

Brix and Baumé.—The Brix hydrometer is the same as the Balling. he Baumé hydrometer used in some canneries was originally designed for e determination of salt in brines and was originally calibrated by deterining the resting point of the hydrometer in water, which was taken as ro on the scale, and the resting point in a 10 per cent salt solution, which as taken as 10° Baumé. Points above or below 10° were divided into ual scale divisions. See Table 11 for relation between Brix and aumé degree and paragraph on brine hydrometers for salometer egree.

TABLE 11.—RELATION OF BALLING, SPECIFIC GRAVITY, AND BAUMÉ
(From "*Official and Tentative Methods of Analysis*," Association of Official Agricultural Chemists)

Balling degree or Brix	Specific gravity	Baumé degree	Balling degree or Brix	Specific gravity	Baumé degree
1	1.0038	0.55	38	1.1692	20.80
2	1.0077	1.10	39	1.1743	21.40
3	1.0117	1.70	40	1.1794	21[illegible]
4	1.0157	2.20	41	1.1846	22[illegible]
5	1.0197	2.80	42	1.1898	23.[illegible]
6	1.0237	3.30	43	1.1950	23.50
7	1.0277	3.90	44	1.2003	24.00
8	1.0318	4.40	45	1.2056	24.60
9	1.0359	5.00	46	1.2110	25.00
10	1.0401	5.55	47	1.2163	25.60
11	1.0443	6.10	48	1.2218	26.10
12	1.0485	6.70	49	1.2272	26.70
13	1.0527	7.20	50	1.2327	27.20
14	1.0570	7.80	51	1.2383	27.70
15	1.0613	8.30	52	1.2439	28.20
16	1.0656	8.90	53	1.2495	28.75
17	1.0700	9.40	54	1.2551	29.30
18	1.0744	10.00	55	1.2608	29.80
19	1.0788	10.50	56	1.2665	30.30
20	1.0832	11.10	57	1.2723	30.80
21	1.0877	11.60	58	1.2781	31.30
22	1.0923	12.20	59	1.2840	31.85
23	1.0968	12.70	60	1.2898	32.40
24	1.1014	13.30	61	1.2958	32.90
25	1.1060	13.80	62	1.3017	33.40
26	1.1107	14.35	63	1.3077	33.90
27	1.1154	14.90	64	1.3138	34.40
28	1.1201	15.40	65	1.3198	34.90
29	1.1248	16.00	66	1.3260	35.40
30	1.1296	16.50	67	1.3322	35.90
31	1.1344	17.10	68	1.3384	36.40
32	1.1393	17.60	69	1.3446	36.90
33	1.1442	18.50	70	1.3509	37.40
34	1.1491	18.70	71	1.3572	37.90
35	1.1541	19.20	72	1.3635	38.30
36	1.1591	19.80	73	1.3699	38.80
37	1.1641	20.30	74	1.3764	39.30

Testing Hydrometers.—Owing to the fact that continued use of the hydrometer in hot syrups affects its accuracy, it should be checked frequently by more accurate instruments. Hydrometers with long stems, and therefore of greater distance between divisions, are more easily read than hydrometers with short stems. It is desirable for the canner to have duplicate or triplicate sets of accurate hydrometers. Table 11 gives the relation between specific gravity, Balling degree, and Baumé degree.

Before removing samples from the syrup tank the contents of the tank should be thoroughly mixed. Compressed air may be used to advantage in stirring. In reading the hydrometer the bottom of the meniscus (level of the syrup) is read.

Temperature Corrections.—As previously stated, hydrometers are calibrated for use at a "standard" temperature such as 15.5, 17.5, or 20°C. (60°, 63.5, or 68°F.). The calibration temperature is printed on the stem of the hydrometer. The test must be made at this temperature, or suitable correction must be made. Usually the syrups are at much higher temperatures than those at which the instruments are calibrated. At temperatures above the standard the observed reading will be too low because the higher temperature expands the volume and correspondingly decreases the Brix degree.

In one large California cannery a sample of the hot syrup is passed through a metal coil surrounded by running cold water which cools it in a few seconds to standard temperature. No correction is then necessary.

The magnitude of the temperature correction for each temperature degree varies somewhat with the sugar content (density) of the syrup and with the temperature range. Thus the average correction per degree centigrade at 20 to 30°C. for a syrup of 30° Brix is 0.08° Brix, whereas in the range 90 to 100°C., it is 0.15° Brix per degree centigrade.

A Fahrenheit temperature correction table for syrups for Brix degree will be found in "Official and Tentative Methods of Analysis" of the Association of Official Agricultural Chemists, Washington, D. C., together with extensive tables of Brix, Baumé, and specific gravity of syrups at several temperatures.

For syrups of densities commonly used in canning, *viz.*, 10 to 55° Brix, the average approximate correction in Brix degrees for each degree Fahrenheit above the standard temperature for which a given hydrometer is calibrated, is 0.052° Brix, or for each 10°F. it is 0.52° Brix. Thus a syrup testing 25° Brix at 63°F. would test only 21.12° Brix at 140°F.; or a syrup to test 25° Brix at 63°F. should be made to 21.12° Brix if tested at 140°F. (as is often the case in practice). These relationships are made plain in the following table, which will be found very useful in the syrup room.

Effect of Impurities.—Carbonates and sulfates in the water used in preparing syrup may cause white precipitates during boiling. Iron salts

TABLE 12.—TEMPERATURE CORRECTION TABLE FOR SUGAR SYRUPS
Showing actual Balling reading at observed temperature
(*After Wiegand*)

Temperature Fahrenheit	Degree of syrup desired									
	10	15	20	25	30	40	50	60	70	75
	Actual saccharimeter reading at temperature observed									
32	10.41	15.52	20.62	25.72	30.82	40.98	51.11	61.22	71.25	76.29
41	10.37	15.44	20.52	25.59	30.65	40.75	50.80	60.88	70.91	75.94
50	10.29	15.33	20.36	25.39	30.42	40.49	50.50	60.54	70.58	75.61
54	10.22	15.24	20.26	25.29	30.31	40.34	50.36	60.40	70.42	75.46
57	10.16	15.17	20.18	25.19	30.21	40.22	50.23	60.26	70.28	75.32
61	10.08	15.19	20.10	25.10	30.11	40.12	50.12	60.14	70.16	75.18
62	10.03	15.03	20.03	25.04	30.04	40.04	50.04	60.05	70.05	75.06
63	10.00	15.00	20.00	25.00	30.00	40.00	50.00	60.00	70.00	75.00
64	9.97	14.97	19.97	24.97	29.97	39.97	49.97	59.97	69.97	74.98
68	9.92	14.91	19.91	24.90	29.90	39.90	49.90	59.90	69.92	74.94
72	9.71	14.69	19.69	24.68	29.68	39.67	49.66	59.68	69.71	74.75
75	9.59	14.57	19.56	24.54	29.54	39.53	49.50	59.54	69.57	74.60
79	9.46	14.44	19.42	24.40	29.39	39.38	49.34	59.38	69.42	74.45
82	9.32	14.30	19.28	24.24	29.24	39.22	49.18	59.22	69.28	74.39
86	9.18	14.13	19.18	24.08	29.06	39.02	49.06	59.12	69.12	74.14
90	9.02	13.91	18.97	23.92	28.92	38.90	48.86	58.90	68.97	74.02
93	8.86	13.84	18.79	23.76	28.76	38.72	48.70	58.74	68.81	73.83
97	8.68	13.67	18.62	23.59	28.59	38.54	48.53	58.58	68.65	73.67
100	8.51	13.49	18.45	23.41	28.41	38.36	48.35	58.40	68.49	73.51
104	8.33	13.29	18.27	23.21	28.21	38.18	48.17	58.22	68.31	73.35
108	8.14	13.11	18.07	23.01	28.01	38.00	47.99	58.04	68.15	73.19
110	8.04	13.01	17.97	22.91	27.91	37.90	47.90	57.95	68.07	73.11
112	7.94	12.99	17.87	22.81	27.81	37.80	47.81	57.86	67.98	73.03
115	7.73	12.70	17.66	22.61	27.61	37.60	47.61	57.68	67.80	72.77
117	7.62	12.59	17.55	22.51	27.51	37.50	47.51	57.59	67.71	72.76
119	7.51	12.48	17.46	22.41	27.41	37.40	47.41	57.50	67.62	72.75
121	7.40	12.37	17.33	22.31	27.31	37.30	47.31	57.40	67.53	72.58
122	7.29	12.26	17.22	22.20	27.20	37.20	47.21	57.30	67.44	72.49
124	7.19	12.16	17.11	22.10	27.10	37.09	47.11	57.20	67.35	72.40
126	7.08	12.06	17.00	21.99	26.99	36.98	47.01	57.10	67.26	72.31
128	6.97	11.96	16.89	21.88	26.88	36.87	46.91	57.00	67.17	72.22
130	6.86	11.85	16.78	21.77	26.77	36.76	46.81	56.90	67.08	72.13
131	6.74	11.74	16.67	21.67	26.67	36.71	46.70	56.80	67.00	72.04
133	6.61	11.61	16.56	21.56	26.56	36.54	46.61	56.70	66.91	71.95
135	6.48	11.48	16.45	21.45	26.45	36.43	46.57	56.60	66.82	71.86
137	6.36	11.36	16.34	21.34	26.34	36.22	46.40	56.56	66.73	71.77
139	6.24	11.24	16.23	21.23	26.23	36.21	46.29	56.40	66.65	71.68
140	6.18	11.12	16.12	21.12	26.12	36.10	46.18	56.30	66.57	71.59
149	5.47	10.46	15.49	20.49	25.51	35.52	45.64	55.79	66.05	71.12
158	4.82	9.80	14.86	19.87	24.90	34.94	45.10	55.68	65.73	70.65
167	4.00	9.10	14.16	19.21	24.26	34.34	44.57	54.73	65.01	70.16
176	3.38	8.61	13.46	18.54	23.62	33.74	43.94	53.61	64.50	69.67
185	2.56	7.62	12.70	17.79	22.90	33.08	43.32	53.18	63.96	69.15
194	1.74	6.84	11.94	17.03	22.15	32.42	42.70	53.04	63.42	68.63
203	0.86	5.98	12.11	16.23	21.39	31.65	42.03	52.41	62.83	68.10
212	0.01	5.13	10.28	15.46	20.61	30.97	41.36	51.78	62.24	67.58

in the sugar may cause darkening of the syrup or precipitation in the can. Soft water is therefore preferable to hard water in the preparation of syrups for canning.

Spoiling of Syrups.—If the syrup is used during the day upon which it is prepared, there is little danger of spoiling. If, however, the pipes between the syrup tank and the syruping machines are allowed to stand several days unused and uncleaned, enough yeast or bacteria may develop to cause disagreeable flavors, ropiness, or fermentation.

On this account syrup lines and tanks should be kept clean and as nearly sterile as possible.

The Effect of Composition of the Fruit upon the Balling of Syrup Used. Very sour fruit requires more sugar, *i.e.*, a more concentrated syrup, than fruit of the same variety of lower acid content, in order to produce the same degree of sweetness as judged by taste, and, conversely, overripe fruit will require less sugar to produce the same degree of sweetness as judged by taste.

Effect of Fill of Can on Balling Degree of Syrup.—A can in which the fruit is packed tightly will require a more concentrated syrup than a loosely filled can, because of the greater ratio of fruit to syrup. Therefore, it is sometimes necessary in the packing of soft fruit to increase the Balling degree of the syrup so that the cutout test will be satisfactory. Some commercial canners cut hundreds of cans from their daily production in order to maintain uniform grades.

Syruping Machines.—The first method used commercially for adding syrup to the cans was by means of what is known as the "dip syruper" now no longer used. In this syruping machine the cans were immersed into a tank of syrup. The method was unsanitary and wasteful of syrup.

A syruper now in wide use in all fruit-canning districts is that of the displacement type. The can is filled automatically to a predetermined level by the device shown in Fig. 16. Automatic syrupers are accurate, are not wasteful of syrup, are sanitary, and have great capacity.

A third style of syruping machine, in which the cans are filled by passing beneath streams of syrup, is in use by several of the large canning organizations in California. The excess syrup flows into a reservoir beneath the machine and is returned by a rotary pump. In still another syruper (the Judge syruper) a measured amount of heavy syrup is added to each can which is (after exhausting) then filled with hot water.

Brines and Brining.—Most factories use dilute brines of 1 to 2 per cent salt content for vegetables, and ripe olives are canned in brines varying from 2 to 4 per cent salt.

Salt for canning purposes should be at least 99 per cent sodium chloride, NaCl, and that of lower purity than 98 per cent should not be used. Iron compounds in the salt will cause discoloration of the brine and precipi-

tation in the can, and the iron may combine with the tannin of the vegetables to cause blackening. Calcium salts may cause a white precipitate on boiling or sterilizing and a toughening of the product. Bicarbonate of calcium by boiling is transformed into carbonate and is precipitated as such. The presence of excessive amounts of sodium and magnesium sulfates or other sulfates may give a bitter flavor to vegetables.

For reasons similar to those given for salt, the water for brines should be as pure as possible. The brine should be boiled before use in order to cause coagulation and precipitation of calcium salts and other impurities and it should be allowed to settle or be filtered before use if a heavy precipitate forms.

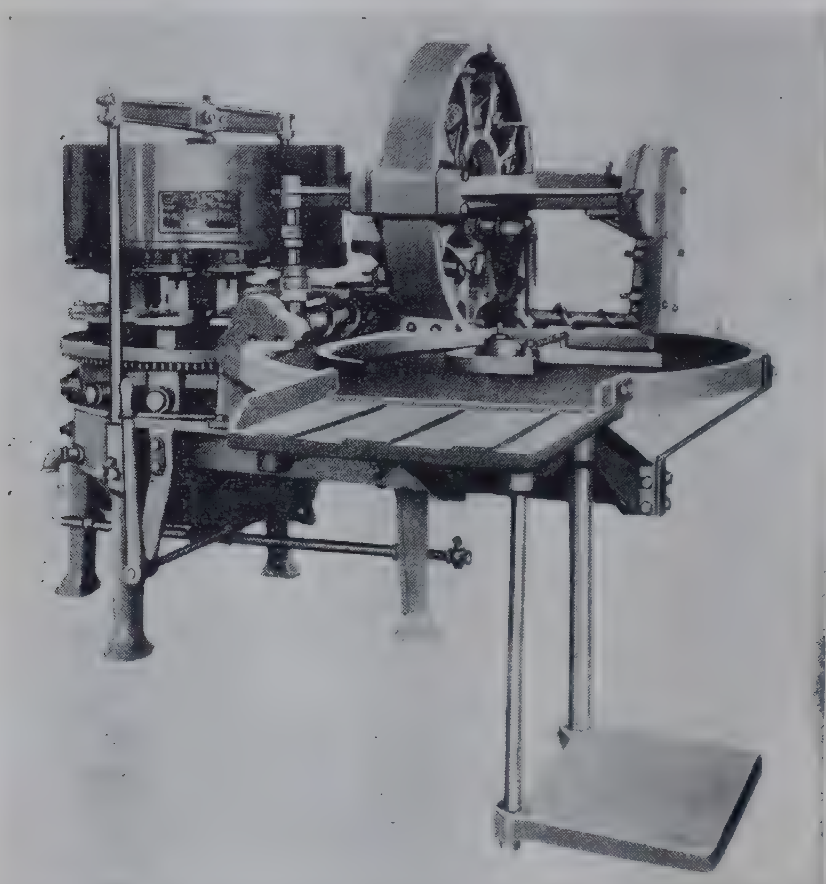

FIG. 16.—Can-draining and syruping machine. (*Courtesy Food Machinery Corporation.*)

Hydrometers for Brines.—Two different hydrometers are used in the testing of brines for canning. In the canning of olives, the brine is normally tested by what is known as a "salometer." A brine testing approximately 100 salometer will contain 26 per cent of salt.

The Baumé reading multiplied by 4 corresponds approximately to the salometer reading (see also Table 76). The brine used for corn and peas usually contains a small amount of sugar. The amount of sugar added will vary according to the grade and according to the practice of the cannery but is usually from 3 to 10 per cent.

Owing to the fact that brine is very much cheaper than syrup, the brining machines are often less perfect in design and operation than the syruping machines and often consist merely of an open pipe from which a stream of brine flows into cans beneath which the cans of vegetables or olives pass on a chain conveyer. The cans are filled to overflowing and the excess of brine is allowed to flow to the sewer. Many factories at the present time, however, are using the automatic displacement type of syruping machine commonly employed in canning fruit.

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CHAPTER IX

EXHAUST AND VACUUM

As employed in the canning industry, "exhausting" usually signifies heating the can and contents before sealing. It may also mean treatment of the container under a mechanically produced vacuum. In either case it has for its purpose the objects listed below.

Objects of Exhausting.—One of the most important objects of exhausting is to remove air from the contents of the can and thereby reduce corrosion of the tin plate, since corrosion is favored by the presence of oxygen.

A second object is to produce a vacuum so that the ends of the can on the grocer's shelf will be concave and thus indicate to the prospective purchaser that it is in sound condition. Convex or bulged ends usually indicate gaseous spoilage.

A third very important purpose of exhausting is to prevent undue strains upon the can during sterilization.

Thorough exhausting by heat tends to prevent overfilling of the can but also permits a greater fill of soft products, such as berries.

Relation of Temperature of Exhausting to Degree of Vacuum.—A No. 2½ can of fruit or vegetables should, after sterilization and cooling, show a vacuum of 8 to 15 in. when tested with a can-vacuum testing gauge. The vacuum will vary according to the temperature of the can at time of sealing. The usual exhausting temperature for fruits is 180 to 205°F., this range of temperature referring to the temperature of the exhaust box. The temperature in the center of the can ordinarily reaches 170 to 180°F. Table 13, showing the relations between the temperature of the can before sealing and the vacuum in the can at room temperature after sterilization, has been compiled and published by Magoon and Culpepper in *U. S. Department of Agriculture, Bulletin* 1022.

Large cans, such as gallon and No. 10 sizes, if exhausted too thoroughly will become paneled, *i.e.*, the sides of the can will be drawn in, and in certain cases the can may collapse. The No. 3 cans or smaller sizes may be exhausted very thoroughly without danger of collapsing.

Magoon and Culpepper have made a study of the relation between the temperatures of the contents of the can and the vacuum in inches after sterilizing and cooling. The authors have calculated the values for the vacuum in inches for a noncontractile receptacle containing air and saturated vapor when sealed at various temperatures and cooled to the

uniform temperatures of 0, 10, 20, 30, and 40°C. Cans are not perfectly rigid, noncontractile containers and to a certain extent the walls may be drawn inward by the difference in pressure inside and outside the can. To that extent the internal pressure increased, *i.e.*, the vacuum decreased. Magoon and Culpepper's curves will be found in Fig. 17. As the sealing temperature is increased, the vacuum in the can increases on cooling. Thus cans sealed at 70 and 50°C., respectively, and cooled to 20°C. show

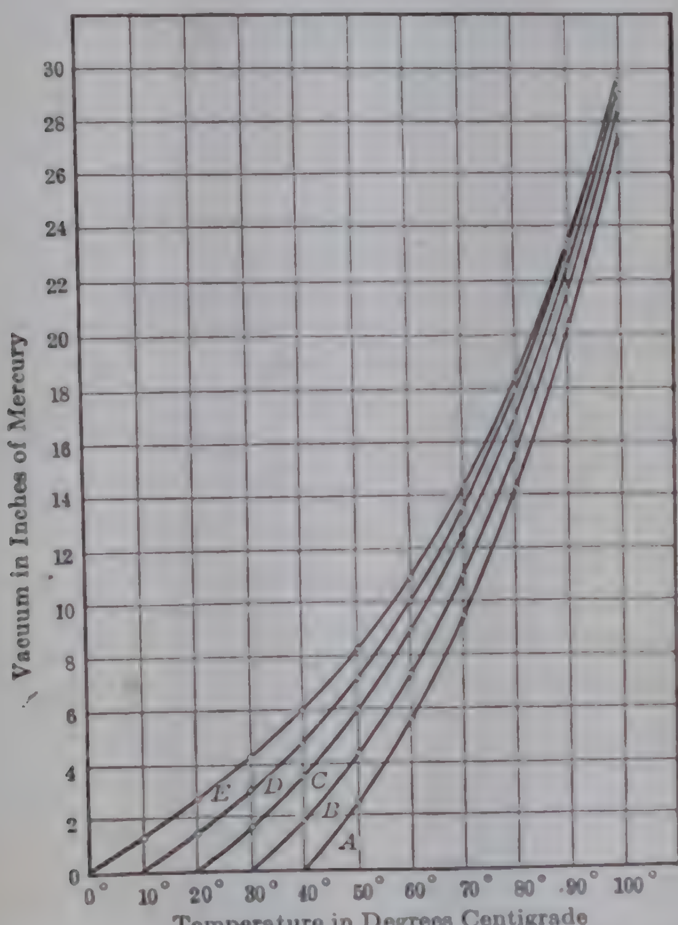

FIG. 17.—Theoretical vacuum curves for a noncontractile can containing air and sufficient water to give saturation when sealed at different uniform temperatures (ranging from 0 to 100°C.) when read at 0, 10, 20, 30 and 40°C. Calculations are based upon mean barometric pressure. Curves for readings made: *A* at 40°C.; *B* at 30°C.; *C* at 20°C.; *D* at 10°C.; *E* at 0°C. (*After Magoon and Culpepper.*)

about 12.3 and 6 in. vacuum respectively. The curves also show that the temperature of the can, at the time of determining the vacuum, markedly affects the vacuum reading. Thus a can sealed at 70°C. should show a vacuum of about 12.3 in. when cooled to 20°C., of about 10.9 in. when cooled at 30°C., and 14.3 in. when cooled to 0°C. This relation explains why cans may leave the cannery in apparently good condition and on storage in a hot climate develop slight internal pressure and the appearance of mild "springers" or spoiled cans. It also explains why cans are more liable to collapse during shipment in cold weather; the low tempera-

ture increases the vacuum and hence in effect the atmospheric pressure on the walls of the can.

Cans show less vacuum at high altitudes than at low because of the decrease in barometric pressure as the altitude increases. In fact a can which shows, for example, 5 in. vacuum at sea level will show a positive pressure and may become a mild springer at 10,000 ft. elevation (for further discussion of this point see Clark, Shostrom, and Clough).

Magoon and Culpepper have made an experimental study of the effect of sealing temperature on the vacuum in inches in cans of several important canned foods. They have also determined the effect of processing temperature upon the vacuum. Table 13 gives some of their data on these points.

TABLE 13.—RELATION OF VACUUM TO TEMPERATURE OF SEALING AND PROCESSING TEMPERATURE

(After Magoon and Culpepper)

Product	Temperature of sealing		Temperature of processing		Vacuum inches of mercury
	°C.	°F.	°C.	°F.	
String beans	70	158	100	212.0	12⅛
	70	158	116	240.8	11¾
	70	158	121	249.8	11¾
	80	176	100	212.0	15⅜
	80	176	116	240.8	13¾
	80	176	121	249.8	13$\frac{1}{16}$
Corn	70	158	100	212.0	12
	70	158	116	240.8	9⅛
	70	158	121	249.8	9⅞
	80	176	100	212.0	15⅝
	80	176	116	240.8	14⅛
	80	176	121	249.8	13¾
	45–50	...	100	212.0	3
	55–60	...	100	212.0	7.6
	65–70	...	100	212.0	11
	75–80	...	100	212.0	14.6
	95–100	...	100	212.0	21.2
Sweet potatoes	70	158	100	212.0	13⅛
	70	158	116	240.8	11
	70	158	121	249.8	10⅝
	80	176	100	212.0	14
	80	176	116	240.8	13½
	80	176	121	249.8	9

The data indicate that the higher the temperature of sterilization the lower the vacuum in the can, a fact probably accounted for by greater

evolution of gas at the higher temperatures tending to reduce the vacuum (expressed in inches of mercury).

Effect of Temperature of Head Space.—The temperature of the head space at time of sealing was found by Magoon and Culpepper to affect

TABLE 14.—EFFECT OF TEMPERATURE OF HEAD SPACE, AT SEALING, ON VACUUM
(*After Magoon and Culpepper*)

Product	Length of exhaust in steam, minutes	Vacuum, inches, cans sealed at once	Vacuum, inches, head space cooled but solid content not cooled
	2	15	
Tomatoes No. 2 can....................	4	16⅞	
	6	17½	
	2	15	3½
	4	15	6½
Tomatoes No. 3 can....................	6	16	
	5	....	8

the vacuum in a can as shown by Table 14. The reason for this relationship is twofold; at the higher temperature the air present expands to a greater extent and more of the air is displaced with steam.

Meaning of Vacuum.—The vacuum in a can of food is nothing mysterious or difficult to understand; it is merely the difference in pressure between the pressure of the atmosphere inside the can and that outside the can. For example suppose that the barometric or atmospheric pressure of the outside atmosphere is 29.5 in. and of that inside the can 17 in. The "vacuum" inside the can is then 29.5 − 17 = 12.5 in. This is the value that would be indicated on the dial of a vacuum gauge used in testing the can. Thus it can be seen that "vacuum" in the can is governed, not only by the pressure in the can, but also by the outside atmospheric pressure.

Disappearance of Oxygen.—Analysis of the gaseous contents of an unenameled can of food that has stood for a few weeks will show practically complete absence of oxygen. The gas will be found to be principally nitrogen with a small amount of carbon dioxide—unless corrosion has been appreciable, when hydrogen will also be found. The oxygen sealed in the can rapidly combines with the plate and to some extent with the food product, hence is no longer present as a gas. The intern[illegible] gaseous pressure is correspondingly decreased, *i.e.*, the va[illegible] [illegible] increased. Since approximately one-fifth of the atmosphere co[illegible] of oxygen, this change in its state may markedly increase the vacu[illegible]

Exhausting and Corrosion.—While, as will be pointed out in greater detail later, the corrosion of tin plate is to a large extent due to local cell action and occurs for the most part in the absence of gaseous oxygen, nevertheless the presence of oxygen in the can during and shortly after processing may intensify initial corrosion of the plate and thus favor subsequent corrosion in the absence of oxygen. At any rate it is a well-demonstrated fact that oxygen present in the head space and in the tissues of such products as apples and fruit juices when the can is sealed will greatly shorten the life of the canned product by favoring subsequent corrosion with evolution of hydrogen gas or pin holing.

This subject is discussed further in Chap. XIV.

Effect of Size of Head Space.—Other things being equal the vacuum in the can after sealing and cooling will vary inversely with the volume of the head space at the time of sealing, as will be seen from the following consideration. If a can is filled completely with the food product at time of sealing, the head space formed by cooling of the contents after sealing will be filled principally with "nothing," *i.e.*, there will be practically no permanent gas present and therefore very little pressure, or conversely there will be a very high vacuum. If, on the other hand, there is a large space at the time of sealing this space will contain considerable air which after the can is sealed and cooled will exert pressure and give a correspondingly lower vacuum.

Determining the Vacuum in Cans.—The usual method of determining the vacuum is by means of a vacuum gauge fitted with a hollow steel point protruding through a heavy, soft-rubber gasket. In taking the vacuum of a can the hollow point is forced through the lid of the can, the rubber gasket making a gastight seal and preventing loss of vacuum. The vacuum in inches is indicated by a needle on the dial of the gauge. The gauge often is constructed to indicate both pressure and vacuum since cans will often exhibit a "negative" vacuum, *i.e.*, possess a pressure in excess of atmospheric pressure.

Types of Exhaust Boxes.—In the exhausting of fruits the cans and contents are ordinarily exposed to high temperatures (185 to 205°F.). A long exhaust at a moderate temperature is to be preferred to a short exhaust at a high temperature if one considers only the effects produced rather than efficiency of operation or cost.

The disk exhaust box consists of a rectangular metal box in which are several rows of large metal disks from 15 to 18 in. in diameter fitted with cog gears which mesh together. Above the disks are curved iron rods which guide the cans through the exhaust box (see Fig. 18). The cans travel down one row of disks and back the next. Usually the exhaust box contains three to four rows of disks. The number of rows, however, and

the length of the exhaust box vary according to the capacity desired and the nature of the product to be exhausted.

Cable Exhaust Box.—This is the simplest type of exhaust box and consists of a narrow, shallow, rectangular metal container through which passes a steel cable which carries the cans.

In one modification of the cable exhaust box the cable is replaced by a chain conveyer. One of the objections to the chain or cable exhaust box is that the cans sometimes become jammed, causing delay and inconvenience.

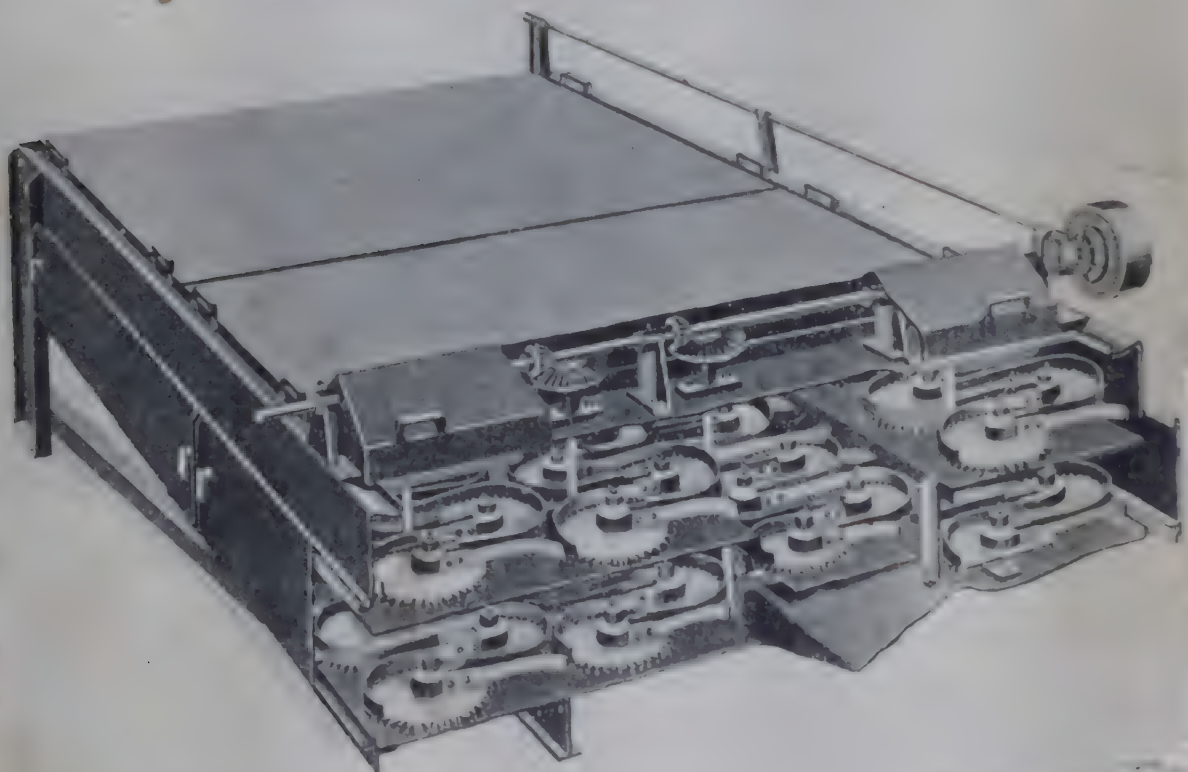

Fig. 18.—Exhaust box with lid removed to show method of conveying cans. (*Courtesy Food Machinery Corporation.*)

A rotary exhaust box, in which the cans are carried through a steam-filled cylinder on a reel, has recently been developed.

Where floor space is limited the circular exhaust box, in which the cans follow a circular or spiral path in passing through the box, is very desirable.

For products which are pasteurized in the cans below 212°, it may be advisable to pass the filled cans through a shallow tank containing water heated to the desired temperature, *e.g.*, in the canning of citrus fruits.

Exhausting by Mechanical Vacuum.—Practically all food products that are sterilized in glass jars are exhausted under a mechanically produced vacuum instead of by heat, and this process has been applied for many years to the canning of coffee in cans, to the exhausting of canned fish and fish products, and to preserves, jellies, etc., in glass. Mor

many other canned products. It is used to som
asparagus, peaches, spinach, and other commo
The pretreatment and the operation of the va
must be adjusted to suit the product being cann
in Chap. XIII).

Filling Cans with Precooked Product.—In t
customary to cook the product with a small amou
corn hot before processing. Exhausting in this ca
same is usually true of peas, pumpkin, and sweet

Wiegand, of the Oregon Agriculture Colleg
same process may be used to advantage in the c
tomato products, such as tomato purée and to
canned hot and sealed without exhausting. Oran
handled in this manner.

Exhausting of Solder Top Cans.—The solder
out of existence, insofar as its commercial use fo
is concerned.

It is customary to fill the container with th
brine or syrup, and seal the lid to the can with so
in the center of the lid being left open. The can
steam in the exhaust box, or otherwise heated, afte
closed with a small drop of solder.

RELATION OF EXHAUSTING TEMPERATURE TO
DURING PROCESSING

It has long been recognized by canners that
internal pressure because of the expansion of gases
during sterilization, and that this pressure is grea
sealed at relatively low temperatures than when se
temperatures. The relation between the tempera
the can at the time of sealing and the pressure deve
during sterilization at various temperatures has b
tively by Magoon and Culpepper.

Theoretical Values for Water and Air.—The au
the theoretical values for pressures developed in no
filled with air and sufficient water to give satu

the temperature of processing. A can sealed at 80°C. (176°F.) develops about 14 lb. pressure at 109°C. (228.2°F.), about 22.3 lb. at 116°C. (240.8°F.), and about 26.5 lb. pressure at 121°C. (249.8°F.). A can sealed at 50°C. (122°F.) develops at 100°C. (212°F.) about 14.7 lb. and at 121°C. (249.8°F.) about 30.7 lb. pressure.

Experimental Values for Water and Air.—In determining the experimental values for water in No. 2 cans, Magoon and Culpepper found that: (1) the pressures developed were always below the theoretical; (2) the higher the retort temperature the greater the variation from the theoretical pressures; (3) the higher the initial temperature, the nearer the theoretical does the pressure during sterilizing come; (4) larger cans show a somewhat greater divergence from the theoretical than the smaller cans; and (5) the smaller the head space the lower the pressure obtained.

The rapid rise noted during the first few minutes of heating is due to expansion of the air in the can.

Increase in Volume of Can and "Buckling."—The increase in volume of the can varies with its internal pressure. Large cans sometimes buckle, *i.e.*, become permanently distorted along the head seam, from excessive internal pressure.

Increase in volume of the container causes decrease in pressure, a fact which explains some of the deviation of experimental curves from the theoretical and the sudden drops in pressure shown by some of the experimental curves of Magoon and Culpepper. They have found that the can may increase in volume 5 per cent or more under normal canning operations.

According to Bitting an internal pressure of 30 lb. or more is required to buckle a No. 2 can, about 20 lb. for Nos. $2\frac{1}{2}$ and 3 cans, and about 10 lb. for No. 10 cans.

Strain on Can.—The actual strain on the can during processing can be obtained by subtracting the retort pressure from the pressure in the can. Thus, if the retort is operated at 10 lb. steam pressure and the pressure in the can is 18 lb. per square inch, the effective pressure or actual strain on the can is 18 minus 10, or 8 lb. per square inch.

When the steam is turned off, the retort pressure rapidly drops to zero. The can does not cool so rapidly as the retort, and consequently it may remain at or near the original temperature and pressure for a short time. It is for this reason that large cans are often cooled under air pressure in the retort to avoid buckling.

Glass Containers.—During processing some glass containers are not hermetically sealed or are so sealed that slight internal pressure will raise the lids; consequently, the jars are not subjected to internal pressure, or at most to only very slight pressure. Some types of glass containers are however, hermetically sealed. The containers of this type are usually

filled hot and in addition are exhausted under a mechanical vacuum before sealing, in order to reduce internal pressure to a minimum. During sterilization in steam retorts, air pressure is applied to hold the caps in place.

Glass containers sealed hot and allowed to cool develop approximately the theoretical vacuum because of the fact that the walls do not contract or expand appreciably, as do those of tin containers.

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CHAPTER X

PROCESSING OF CANNED FRUITS AND VEGETABLES

"Processing," *i.e.*, heating or sterilization of canned foods, is the most important operation in canning. "Sterilization" is used here in a qualified manner, for as pointed out in a subsequent section, the canned product often is not sterile in a bacteriological sense because of the presence of heat-resistant aerobes or thermophiles that do not develop in the canned product because of unfavorable conditions. The word "processing" is, therefore, preferable to the word "sterilization" in this connection. Its principal purposes are: (1) to render the product stable against spoilage by microorganisms and (2) to improve the texture, flavor, and appearance by cooking. The first is the more important object. Although processing should be thorough enough to insure good keeping quality, it is desirable with many canned fruits and vegetables that this object be accomplished in as short a period as possible in order that the product will not be overcooked and thereby injured in flavor and texture. Because of many serious losses of canned fruits and vegetables in the past through insufficient sterilization, canners at the present time are inclined to overprocess their products.

PRINCIPLES OF PROCESSING

The fundamental principles of processing have been very thoroughly investigated in the Research Laboratory of the National Canners' Association at Washington, D. C., under the direction of W. D. Bigelow and J. R. Esty, by Magoon and Culpepper in the Bureau of Plant Industry of the U. S. Department of Agriculture, by Dickson of Stanford Medical hool, Meyer of the University of California Medical School, Ball of the erican Can Co., Thompson of Iowa, Rosenau of Harvard, Ford and ell of the Glass Container Association and University of California, others.

Time and Temperature.—In the processing of canned foods both time d temperature are important, since as the temperature increases, the sterilizing effect is rapidly increased: thus sterilization at 250°F. is pproximately 100 times as rapid as at 212°F. Therefore, in specifying temperatures for different products it is essential to specify the time also.

Effect of Condition of Raw Material on Sterilizing.—The experience of canners has proved that fruits or vegetables which contain a large per cent of moldy or otherwise decomposing raw material are very much more

difficult to sterilize than the same products in a sound condition. Overripe fruit, because of the fact that it softens and forms a compact mass in the can and retards heat penetration, is more difficult to sterilize than fruit of firmer texture, which retains its normal shape and texture. The blanching of fruits or vegetables in boiling water or steam before canning removes some of the microorganisms from the surface of the raw products and in this way reduces their tendency to spoil. It has been proved, however, that blanching of vegetables does not materially reduce the death temperature of resistant spore-bearing organisms, and it is probable that its principal benefit, as it affects sterilization, lies in removal of some of the microorganisms rather than in any sterilizing effect.

Modes of Heat Transference.—Heat is transferred from the processor to the canned product by two important means, *viz.*, by conduction and by convection. The conduction of heat may be described as the transfer of heat between adjacent molecules.

There are wide variations in the conductivity of various materials. Iron, for example, is known as a good conductor, and when one end of an iron rod is held in a flame the opposite end will, in time, rise in temperature. Wood is known as a very poor conductor.

The transfer of heat in products containing syrup or brine is principally by convection, or transfer of heat by currents set up in the liquid. Heated liquids tend to expand, thereby decreasing in density, a condition which causes them to rise.

Transfer of heat by conduction is very much slower than by convection. Therefore, pasty or semisolid products, in which convection currents are sluggish or absent, require very long periods of sterilization. Examples are corn, pumpkin, and sweet potatoes. Products, on the other hand, which are suspended in brine or syrup, heat very rapidly, and, other conditions being equal, require a very much shorter period of sterilization than semisolid products. Examples of canned foods in which convection is the principal means of heat transfer are all varieties of fruits, canned peas, and string beans.

Typical Heat-penetration Curve.—The rate of heat penetration in canning is determined by the temperature at the center of the can. If a thermometer is inserted in the center of the can of food and the can supported in a sterilizer which is at constant temperature, three distinct periods will be noted. During the first stage of the heating process, the center of the can rises in temperature very slowly, in spite of the fact that during this interval heat units are entering the can at a much higher rate than later in the sterilizing process. During the first stage the material near the outside of the can, however, absorbs nearly all of the heat which enters the can and the heat, therefore, does not reach the center of the can. During the same period the contents of the can near the sides and ends

have reached a high temperature and the temperature at the center of the can rises very rapidly. In the third stage of the heating process the contents of the whole can have approached the temperature of the sterilizer, the temperature gradient has become very low, and heat enters the can slowly. These conditions are shown graphically in Fig. 19.

Temperature-measuring Devices.—Nearly all commercially operated steam-pressure retorts are equipped with automatic temperature-recording thermometers. This style of thermometer ordinarily consists of a long, vapor-filled metallic tube at one end of which is a bulb inserted into the retort and at the other end of which are a dial and ink-filled stylus. The vapor-filled instrument has largely displaced the mercury-filled one formerly used, because the mercury-filled tube is subject to changes in temperature of atmosphere outside the processor and consequently

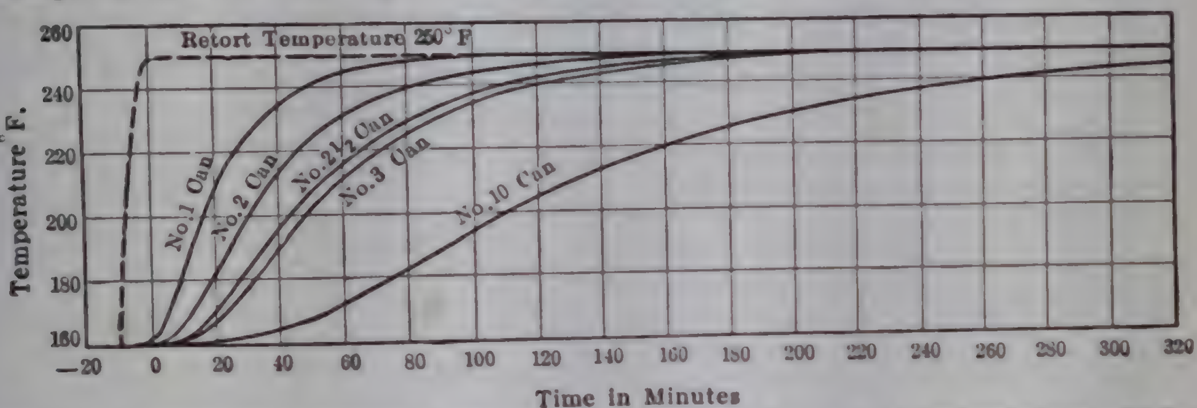

Fig. 19.—Theoretical minimum heat penetration curves for cans of various sizes. (*After Bigelow.*)

often gives erroneous readings. For further discussion see section on temperature control.

The "telltale" thermometer is very generally used by canners. It consists of a small maximum thermometer which operates in the same manner as a clinical thermometer. It is generally attached to a removable screw cap and is protected by a metal sheath. Readings obtained by this style of thermometer are likely to be very inaccurate, since the metal cap and sheath conduct heat rapidly. A more satisfactory method of using the telltale thermometer is to attach it to a small piece of wood in such a manner that the bulb of the thermometer rests in the center of the can. Cans containing telltale thermometers may be placed at various points in the sterilizer and a fairly accurate comparison of the temperatures obtained. The can, however, must be removed for reading the thermometers.

Resistance thermometers have also been used successfully. The resistance unit consists of a small coil of platinum wire wound on a porcelain tube and placed at the center of the can. It is connected to a Wheatstone-bridge circuit. Resistance of liquids varies inversely with the temperature.

A more convenient temperature-recording device is the thermocouple, which is made of very small copper and constantan alloy wires soldered together. The differences in potential generated at the point of contact with the two metals vary with the temperature. The opposite ends of the wires are kept at a constant temperature by immersion in a mixture of ice and water at 0°C., or a compensating potentiometer is used.

The electromotive force developed is measured by a potentiometer which can be calibrated by immersing the thermocouple in water at known temperatures, *e.g.*, in boiling water and in melting ice. This method of determining the rate of heat penetration in canned goods has been highly developed by various laboratories, particularly the National Canners, the Glass Container Association, and the American Can Company. With a set of thermocouples it is possible to determine the temperature of cans in an experimental agitating cooker or in commercial sterilizers in which the cans are not agitated. As many as 20 cans may be tested simultaneously with this outfit. Instrument companies can supply the necessary standard wires, such as copper and constantan or other suitable alloy together with compensating-cold-junction potentiometer. The method of assembly is described by Parcell. For the ordinary commercial cannery, however, the telltale thermometer is sufficiently accurate.

Magoon and Culpepper make the point that the thermocouple is not an accurate heat-measuring device because of the high conductivity of the wires as compared with the conductivity of most foods. They state further that a glass thermometer is to be preferred to the thermocouple because of the low heat conductivity of glass. It is probable, however, that the small wires used in the thermocouple are at approximately the same temperature as the canned food with which they are in immediate contact and that little heat is conducted by the wires themselves to the junction of the two metals. The metal tube covering or sheath for the wires used by Bigelow and associates, however, was found to conduct considerable heat to the centers of the cans, and at the suggestion of Parcell and Ford the couples are now covered with Bakelite or some other poor conductor of heat.

Experimental Retorts.—Magoon and Culpepper used a small retort described by them in *Bulletin* 956. This retort has proved very useful in obtaining fundamental data on heat penetration. Owing to the small size of the retort, equilibrium at any steam pressure desired may be obtained in 10 to 30 sec. It is fitted with a glass thermometer. The top of the mercury column is always in sight and the temperature at the center of the container may be read directly at any time.

Bigelow and his associates have used a small retort in which it is possible to measure the heat penetration by means of a thermocouple in a can that is rotated during heating. It is described fully in *Bulletin* 16-L of the National Canners' Research Laboratory, 1921.

Parcell and others have made use of a commercial size retort in which heat penetration is measured by thermocouples under industrial conditions. The American Can Company at Maywood, Ill., and the National Canners' Association in San Francisco use a special, small agitating retort in which the temperature in the cans can be measured at regular intervals by thermocouples. In addition they make use of several nonagitating retorts.

Effect of Composition of Container on the Rate of Heat Penetration.—The two materials used for containers in the canning of foods are tin plate and glass. Glass is a poorer conductor than iron, the principal constituent of tin plate. Water, the principal constituent of fruits and vegetables, is a poor conductor of heat when convection is prevented, although where convection currents are possible, it heats very rapidly by convection. If convection currents are prevented, as is the case in pasty products, such as corn, or semisolid products, such as pumpkin and spinach, heat penetration is extremely slow and approaches the theoretical minimum penetration for water (see Fig. 19).

The conducting power of any product may be expressed in terms of "diffusivity" which may be defined *as the temperature change produced in a unit cube of material in a unit time by a unit quantity of heat conducted across a unit area of the product per unit difference in temperature.* Diffusivity is constant for any given material.

The diffusivity constant for glass is 0.37, for water 0.084, and for iron 10.8. From this it can be seen that the rate of heat conductance through glass is about one-thirtieth as rapid as through iron or tin plate but 4.4 times as rapid as through water.

Iron or tin plate transfers heat by conductance 120 times as rapidly as water. This fact explains the very slow heat conductance of corn, pumpkin, and sweet potatoes, which are essentially water in composition but of such consistency that convection currents are eliminated. Where convection currents are active, iron will heat only four to eight times as rapidly as water, and under similar conditions water in a glass container will heat approximately as rapidly as the glass of the container.

Bigelow found that in tin, olives reached the temperature of the retort in approximately 10 min.; in glass, the time required was approximately 20 min. In the sterilization of foods, therefore, it is necessary to take into account the slower penetration of heat in glass than in tin.

Effect of Sugar and Salt on Heat Penetration. Salt, sugar, and other crystalloids in dilute solution do not greatly affect the rate of heat penetration. The retarding effect of the salt concentration in the brines normally used in canning is so small as to be negligible. Very heavy sugar syrups, however, may appreciably slow up heat penetration as was proved by Bigelow's investigations in which the center of the can reached the temperature of the retort in about 6 min., where the product was canned in

water. In a 50° Balling syrup, 24 min. were required for the center of the can to reach the temperature of the retort. In a syrup of 10° Balling, approximately 7 min., and in a 20° Balling syrup approximately 9 min., were required. Irish, Joslyn, and Parcell correlated the viscosity of sugar solutions with rate of heat penetration and found a very sharp decrease in the rate at about 60° Balling.

The dissolved sugar increases the viscosity of the liquid and thereby retards convection currents. The retarding effect, however, is not serious at the concentrations used in canning.

Effect of Colloids on Heat Penetration.—It has long been observed that starchy food, such as corn, conducts heat very slowly, and experiments by Bigelow, Magoon and Culpepper, and others have proved that starch is the retarding agent. Bigelow found that the rate of penetration was retarded in proportion to the concentration of starch in solution until a concentration of 6 per cent was reached. Concentrations of starch in excess of 6 per cent had approximately the same retarding effect as the 6 per cent solution. At 6 per cent concentration of starch, the rate of heat penetration approaches very closely the theoretical rate of heat penetration for pure water, where convection currents are eliminated. This undoubtedly explains the observed fact that concentrations of starch in excess of 6 per cent have approximately the same retarding effect on heat penetration as the 6 per cent solution.

Effect of Consistency on Heat Penetration.—A tightly packed can of fruit or of vegetables heats very much more slowly than a loosely packed can. For example, it was shown by Bigelow that a No. 3 can of spinach reached the temperature of the retort in 6 min. at 220°F. where the can contained only 18 oz. of spinach and that 46 min. were required where the can contained 27 oz. of spinach.

In commercial products it is customary to pack blanched spinach into the cans very much less compactly than formerly. Pumpkin and sweet potatoes are packed in cans in practically a solid condition.

Effect of Size of Container.—A longer period of sterilization is required for a No. 10 can of food than for a No. 1 can, for the reason that the distance from the surface of a larger can to the center is greater than in the smaller container and because the ratio of surface to volume is larger in the smaller container.

A No. 1 can contains 11½ fl. oz., and its surface is 45 sq. in. The ratio of surface to volume s/v equals 3.9. A No. 10 can contains 107 fl. oz., it has 175 sq. in. of surface, and s/v equals 1.6. It can, therefore, be seen that the smaller can has a much larger surface exposed per cubic inch of volume. Bigelow and Thompson have determined the effect of the size of the container on the rate of heat penetration and have published tables of factors which show the relative rates of penetration. These factors,

however, apply only to cases in which convection currents are not active, *e.g.*, in the sterilization of corn, sweet potatoes and pumpkin, meats, tightly packed spinach, etc.

The time required for heat to penetrate to the centers of cans of similar form but of different sizes varies approximately with the square of the radii. Thus, if it requires 60 min. for the center of a No. 2 can of corn to heat to 240°F. and the time required for a No. 10 can is desired, the following relations would hold:

$$r \text{ No. } 2 = 1.72 \text{ in.} \qquad (r \text{ No. } 2)^2 = 2.96$$
$$r \text{ No. } 10 = 3.1 \text{ in.} \qquad (r \text{ No. } 10)^2 = 9.61$$

The time required for the center of the No. 10 can to reach 240°F. is then obtained by use of the formula $\frac{(r\ 10)^2}{(r\ 2)^2} \times t_2$, *i.e.*, by the calculation $\frac{9.61}{2.96} \times 60 = 194$ min.

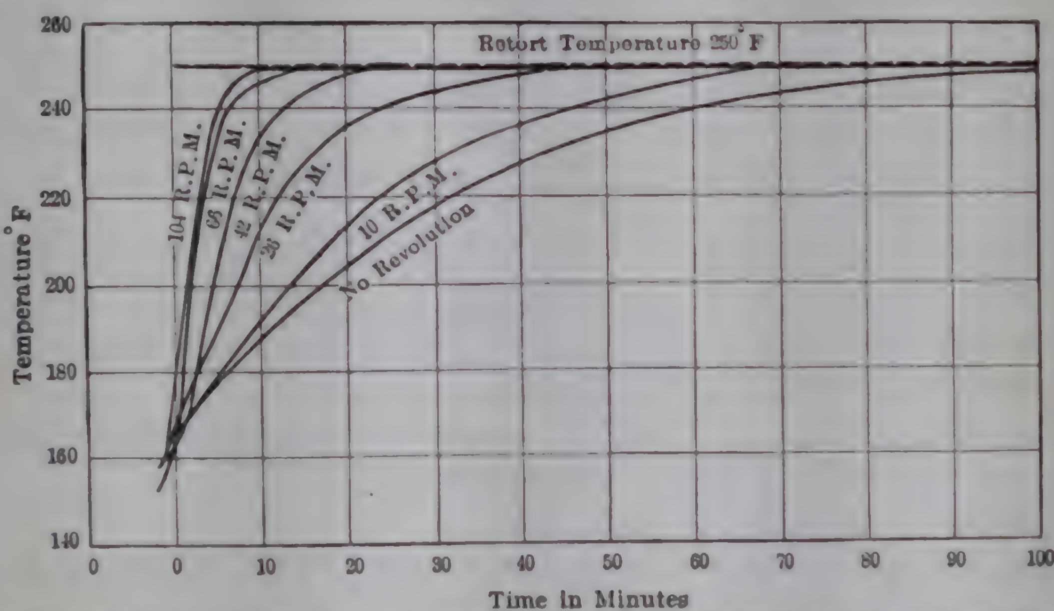

FIG. 20.—Effect of speed of rotation on heat penetration in canned corn. (*After Bigelow.*)

Table 15 gives the factors for relative rates of heat penetration of the more common sizes of sanitary cases.

Influence of Rotation.—It has been proved in commercial practice that agitating cookers are much more effective than cookers in which the cans are not agitated during sterilization. Rotation or agitation of the can mixes the contents and sets up currents which rapidly transfer the heat.

Most of the open processors now used in the commercial canning of fruits are of the agitating type, the cans rotating approximately 11 r.p.m. This rate of rotation is satisfactory for products consisting of large pieces, such as fruits and tomatoes. As the can rotates the large halves of peaches or large pieces of tomatoes fall through the liquid and set up currents.

For products of small size, such as peas and corn, the rate of rotation must be greater in order that the contents of the can be set in rapid motion. This fact is shown in a very striking manner in one of Bigelow's experiments in which it required more than 90 min. for a can of corn to reach the temperature of the retort when the can was not rotated, 70 min. at 10 r.p.m., about 50 min. at 26 r.p.m., about 15 min. at 66 r.p.m., and about 10 min. at 110 r.p.m. It has been found that rotation of the can permits the use of very much higher temperatures for such products as corn (see Fig. 20).

TABLE 15.—HEAT PENETRATION FACTORS FOR VARIOUS SIZES OF CANS
(*After Bigelow*)

Size of can	Factor for determining approximate time for cans of specified size				
	No. 1	No. 2	No. 2½	No. 3	No. 10
No. 1	1.00	1.70	2.30	2.50	5.4
No. 2	0.60	1.00	1.40	1.50	3.2
No. 2½	0.44	0.74	1.00	1.10	2.4
No. 3	0.41	0.68	0.90	1.00	2.2
No. 10	0.19	0.31	0.42	0.46	1.0

The discontinuous agitating retort has long been used in the sterilizing of canned milk, where it is necessary to keep a can in motion to prevent scorching of the contents. Continuous agitating pressure sterilizers have now been perfected and are in use for meat products, corn, spinach, and possibly other products. They are, however, costly. It is believed that they will greatly shorten and simplify the sterilization of canned vegetables.

Effect of Initial Temperature of the Contents of the Container.—The sterilizing value of the retort is markedly affected by the temperature of the contents of the can at the beginning of sterilization. For example, if a can of corn is placed in the retort at 70°F. and another is heated to 160°F. before it enters the retort, it will be found that, with the retort operated at 250°F. if the first can will reach the temperature of 240 at the end of 80 min., the can which entered at 160°F. will reach the temperature of 240°F. in about 40 min. Therefore the center of the first can will receive practically no sterilization at 240°F., whereas that of the second can will receive a sterilization of 40 min. at or above 240°. This fact is of very great practical importance in the sterilization of products which conduct heat slowly.

Thorough exhausting of the can and contents in steam, or the packing of the product in the cans hot, is a very material aid to the sterilization

of canned foods that conduct heat poorly. If the time required for a can heated to a certain temperature before entering the retort is known, the rate of heat penetration in a similar can heated to a different temperature before entering the retort can be calculated. The following example will make this point clearer.

Given a retort operated at 240°F. Can No. 1 enters the retort at 184°F. and reaches a temperature of 226°F. in 60 min. A second can enters the retort at 90°F. Theoretically, both cans will reach the temperature of the retort, 240°F., in the same time. The difference in temperature between can No. 1 and the retort temperature is 56°F.; between can No. 2 and the retort, 150°F. The rate of heat penetration in the two cans will be proportional to the temperature gradient between the sterilizer and the can, or, in other words, the ratio of heat penetration in the two cans will be 56:150. Therefore, in order to reach the retort temperature in the same length of time, can No. 2 must heat $^{150}\!/_{56}$ times as rapidly as can No. 1. Thus, at the end of 60 min., if can No. 1 is at 226°F., it has risen 226 minus 184, or 42°F. Can No. 2 will rise in the same time $^{150}\!/_{56} \times 42 = 112.5$°F. Its temperature will then be 90°F. plus 112.5°F. or 202.5°F.

Bigelow has experimentally checked similar calculations and finds them to hold for products which conduct heat slowly.

Effect of Temperature of Sterilizer.—The higher the retort temperature the more rapid the rate of heat penetration, because of the greater temperature gradient between retort and can. Theoretically, a can of corn in a retort at 240°F. will reach the temperature of the retort in the same length of time as a can in a retort at any other temperature, for example, 250°F. In other words, the time required for the can to reach the final retort temperature will be the same regardless of the retort temperature. However, the can in the retort at 250°F. will reach a temperature of 240°F. in a very much shorter time than a can in the retort held at 240°F. Similar considerations hold for other temperatures.

Influence of Cooling on Sterilization.—The rate of cooling after sterilization affects the sterilization of canned goods. A can of food which is cooled quickly to room temperature after sterilization will require a longer period of processing, other things being equal, than a can cooled slowly, because of the longer period at a sterilizing temperature of the uncooled can.

The increase in temperature during sterilization and cooling after sterilization are governed by the same physical laws. During heating the heat travels from the outside inward and is carried by conduction or convection or both. In cooling, the same modes of heat transfer are active, but the heat is traveling outward. Theoretically, if a can of food is processed until retort temperature is reached and is transferred to water

maintained at the initial temperature of the can, the temperature will follow a curve which is the reverse of the heating curve. Practically, this is not true because of changes in the physical condition of the product during processing; the syrup may become more viscous and thus impede heat transfer, or other changes may occur.

Air cooling is much slower than water cooling because of the lower heat-carrying capacity of air.

Comparative Value of Steam and Water as Heating Medium.—Some canners contend that water is a much more effective heating medium than live steam. However, cans in live steam are soon covered with a film of water and this film is probably as effective as a larger volume of water in conducting heat to the can.

Bigelow and his associates have made numerous experiments to determine the relative heating value of steam and water and have concluded that both are equally effective, provided the source of steam is adequate. However, the presence of air in the steam will greatly reduce its heating value and, therefore, the retort should be thoroughly vented during the "coming-up" period, in order to remove as much of the air as possible. See also section on retort operation.

Theoretical and Practical Processing Times.—C. O. Ball (University of California Public Health Service) has presented in very comprehensive manner the theory of processing, particularly the calculation of processing time at any given temperature when such basic data as death temperature of the organism concerned and rate of heat penetration are known.

Until relatively recent times the only method of determining processing temperature and time was by the cut-and-try procedure. With modern research on heat penetration and death temperatures of spores of the various bacteria concerned in the spoilage of nonacid canned foods, it has become possible to establish on the basis of such data safe processing procedure. The classic work of K. F. Meyer, E. C. Dickson, and their associates on *Clostridium botulinum* (see references at end of Chap. XIV) and that of J. R. Esty and others of the National Canners' Association research staff on spoilage bacteria, together with publication of heat penetration data by various investigators, has laid an excellent foundation for the establishment of processing conditions for various food products. Also, these data form the basis for theoretical considerations, such as those of Ball, who indicates the following procedure in obtaining theoretical process values.

First, the organism responsible for the observed spoilage is isolated, and its death times at various temperatures are determined by heating the organism (usually its spores) suspended in a medium as nearly as possible like that provided by the food itself. Small glass tubes in which the

contents reach processing temperature very quickly are used. The data are then plotted as a thermal death-time curve.

Secondly, the rate of heat penetration to the centers of cans of the food and the rate of cooling are determined, usually, by thermocouples and a potentiometer. These data are also plotted.

Third, by means of the mathematical treatment given by Ball the theoretical process time at a given temperature is calculated. A working knowledge of higher mathematics is required, as the calculations become complex and involved; for this reason those readers interested in the mathematical treatment are referred to the publication cited.

Heat penetration curves possess a logarithmic property. In other words, if time in minutes is plotted against the logarithm of temperature of the center of the can, a straight line is obtained, except during the lag period, that is, the initial stage of the heating curve.

For a curve plotted in nonlogarithmic coordinates, the slope of the curve at any given point is the rate of temperature change at that point and may be obtained graphically by constructing a tangent at that point.

In applying the theoretical process time and temperature to practical conditions, the limitations of the theoretical process must be realized, since practical operating conditions may differ considerably from the experimental. Thus, the consistency of the medium may be different; the rate of rise of retort temperature to operating temperature differ, control of retort temperature during processing may not be uniform; the temperature throughout the retort may not be uniform; or the rates of cooling may differ. Another extremely important factor is that of possible difference in heat resistance of spores of bacteria grown under artificial conditions and of those occurring naturally. Still another uncertainty is the possible presence in the food under natural conditions of a species of organism of greater heat resistance than the one used in the investigation.

For such reasons the theoretical process temperature and time must be verified by making processing tests under practical conditions with a sufficient number of containers to give dependable results; not less than 1,000 cans should be used in such a test. Even after such a test has been made, it is necessary to apply a safety factor in order to compensate for uncontrolled variables.

Nevertheless, the theoretical process time for a given temperature is of very great value and constitutes a distinct forward step.

Effect of Hydrogen-ion Concentration on the Processing of Canned Fruits and Vegetables.—It has long been recognized that acid fruits are very much more easily sterilized than most vegetables. Heating for 10 min. at 75°C. (167°F.) is sufficient to preserve plums or apricots, whereas peas and string beans require at least 4 hr. at the boiling point of

water, 212°F. The most significant difference in composition between these products, as it affects sterilization, is in the acidity.

The work of Bigelow of the National Canners' Association and others has shown that the total acidity of the product determined by titration is not a reliable measure of the effect of the acidity on the sterilization time and temperature, but that the hydrogen-ion concentration is a much better criterion upon which to base the relative time and temperature of sterilization of different materials.

Bigelow and Cathcart have determined the hydrogen-ion concentration of many of the more commonly canned foods by use of the standard hydrogen-electrode equipment. A brief discussion of the terms used in describing hydrogen-ion concentration may make the discussion of this subject clearer.

Discussion of Ionization.—All acids in solution in water, and water itself to a slight extent, dissociate to give hydrogen ions. The chemical formula for water is H_2O, and on dissociation it forms for each molecule of water one hydrogen ion, H^+, and one hydroxyl ion, OH^-. The plus and minus signs indicate that the hydrogen ion carries a plus charge of electricity and the hydroxyl ion a negative charge.

The sour taste of acids is due to the presence of hydrogen ions and the soapy feel and characteristic taste of solutions of alkalies is caused by the hydroxyl ions. Water yields equal quantities of hydrogen ions and hydroxyl ions. If there is an excess of hydrogen ions, the solution is acid in reaction; if an excess of hydroxyl ions, it is alkaline in reaction. Acids as well as alkalies vary in their degree of dissociation. Thus a 1 per cent solution of hydrochloric acid contains a very much higher concentration of hydrogen ions than an equivalent solution of acetic acid, and the hydrochloric acid for this reason is a very much stronger and more active acid than acetic acid. Titration of the two solutions would show them to contain the same total amounts of acid. The hydrogen-ion concentration, therefore, may be considered as an intensity factor for the comparison of acids.

Toxicity of Hydrogen Ion.—The hydrogen ion has been termed the most toxic of all substances. If the acid of fruits was completely dissociated, fruits would be extremely poisonous, but fruits and animal and vegetable tissue of all sorts contain buffer substances which prevent the formation of excessive amounts of hydrogen ions. Nevertheless, the concentration of hydrogen ions in most fruits is sufficient to affect the death temperature of microorganisms very materially.

Methods of Expressing Hydrogen-ion Concentration.—Hydrogen-ion concentration is expressed in several different ways. Expressed as grams per liter, water contains 0.0000001 gram of hydrogen ions per liter, and gooseberries 0.001 gram per liter. Expressed in powers of 10, these

figures become 1×10^{-7} and 1×10^{-3}, respectively. The reciprocals of these quantities are 10,000,000 and 1,000, respectively. The logarithm of the reciprocal of the weight in grams per liter of hydrogen ions is probably the most common means of expressing hydrogen-ion concentra-

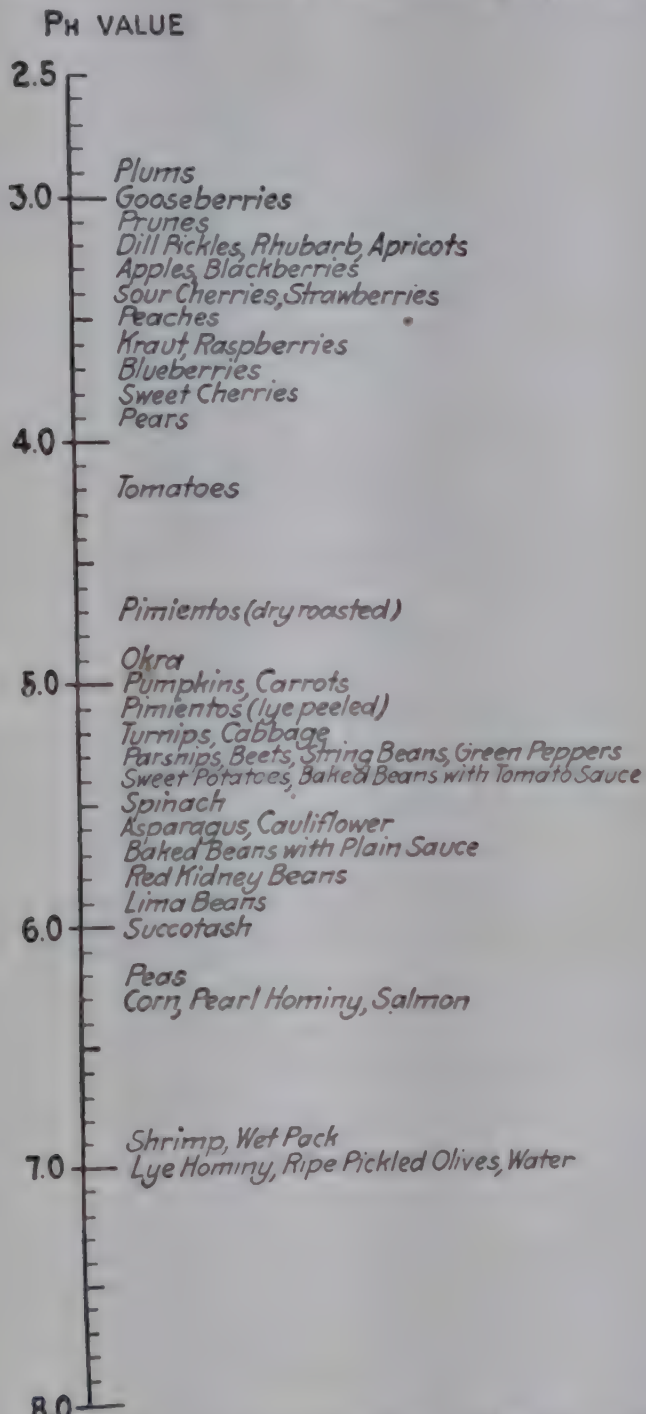

FIG. 21.—pH value of various canned foods. (*After Bigelow and Cathcart.*)

tion. For water it is 7 and for gooseberries 3. This logarithm is called the "pH value." The more acid the substance the lower the pH value becomes.

The following table gives a comparison of the various methods of expressing hydrogen-ion concentration for several canned foods which represent a wide range of pH values.

It will be seen from this table that gooseberries have 10,000 times the hydrogen-ion concentration of lye hominy. This is the reason why the former are very easily sterilized and the latter very difficult to sterilize.

TABLE 16.—HYDROGEN-ION CONCENTRATION OF THE JUICES OF TYPICAL CANNED FOODS
(*After Bigelow and Cathcart*)

Product	Weight of hydrogen ions in grams per liter expressed		Reciprocal of weight in grams per liter	Logarithm of reciprocal (pH value)
	As decimal	In powers of 10		
1. Gooseberries	0.001	1×10^{-3}	1,000	3.0
2. Tomatoes	0.000063	6.3×10^{-5}	15,850	4.2
3. Pumpkin	0.00001	1×10^{-5}	100,000	5.0
4. Corn	0.0000005	5×10^{-7}	1,955,000	6.3
5. Lye hominy, ripe olives, water	0.0000001	1×10^{-7}	10,000,000	7.0

Most fruits have a higher hydrogen-ion concentration and most vegetables a lower concentration than tomatoes. Tomatoes of normal pH value are easily sterilized at 100°C. (212°F.). Pimentos also are usually sterilized at the same temperature (212°F.) and have a hydrogen-ion concentration slightly higher than that of tomatoes. When, however, a pH value of 5 is approached or exceeded, the product enters the class of materials which normally require sterilization under pressure. The accompanying figure after Bigelow and Cathcart illustrates clearly the relative positions of various canned foods in the hydrogen-ion concentration scale. In studying the chart it must be borne in mind that *high pH value* means *low hydrogen-ion* concentration.

Experiments by E. C. Dickson of Stanford University have proved that the death temperature of spores of *Bacillus botulinus* is greatly reduced by the acidification of the medium with organic acids, *e.g.*, citric or acetic acid. Experiments performed by the writer in 1915 proved that peas, string beans, corn, and fish inoculated with spores of *B. botulinus* were sterilized perfectly in 1 hr. at 100°C. by heating in dilute brine acidified with lemon juice to approximately 0.2 per cent acidity expressed as citric. The same products not acidified developed a vigorous growth of the organism, even after 3 hours' boiling in sealed containers, and were very toxic to guinea pigs, producing typical symptoms of botulism and death when administered in small doses. The experiments were repeated by a graduate student (see Cruess, Fong, and Liu) in

the Fruit Products Laboratory at the University of California with similar results. Weiss at the Harvard Medical School and others have since confirmed these results. In California the State Board of Health on the basis of research of K. F. Meyer, J. R. Esty, E. C. Dickson, and others has established pH 4.5 as the dividing line between acid and nonacid foods. Thus the board requires that artichokes canned in acidified brine shall have after canning a pH value of less than 4.5. The writer believes this method has great commercial possibilities for vegetables for salad use.

Household Application of Acidified Brines in Canning.—The "lemon juice" method of vegetable canning was at one time in general use in California for the home canning of vegetables (see Cruess, 1915). For most vegetables canned by this method the brine is acidified with 5 fl. oz. of lemon juice per gallon of brine, *i.e.*, this amount of lemon juice is placed in a gallon measure and brine added to make 1 gal. Some vegetables when canned in this manner possess a slight acid flavor, but this is eliminated if a small "pinch" of baking soda is added when, after opening the can, the vegetables are placed in a kettle for cooking. The canned vegetables possess the full fresh vegetable flavor and are superior in flavor to the same materials sterilized under pressure in the usual manner. However, it was finally deemed advisable to discourage the use of this method since some housewives failed to apply it properly, with resulting danger of botulism. It has been replaced by sterilization of the nonacidified products under steam pressure.

STERILIZATION METHODS AND EQUIPMENT

In the first section of this chapter the theory of sterilization was discussed. In the present section the application of these principles to practical canning operations will be described.

Comparison of Fruits and Vegetables.—The nature of the fruit or vegetable to be canned will affect the type of sterilizing equipment to be selected and will determine the temperature and time of sterilization. All fruits, with the exception of olives, are sterilized at 212°F. (100°C.). The acidity of fruits and acid vegetables, such as tomatoes and rhubarb, makes it possible to sterilize them with safety at 212°F. Other vegetables, on the other hand, because of their low acidity; their hard texture; and during growth, their proximity to the soil where they may be contaminated with spore-bearing organisms, require a much more severe sterilizing process than fruits. Temperatures that would spoil the color, flavor, texture, and appearance of fruits in many cases improve the flavor and texture of vegetables. Vegetables, therefore, are usually sterilized at temperatures above 212°F.

Heat Units Required.—Since the specific heat of most fruits and vegetables is practically that of water, the error is small if we assume that

the same amount of heat will be required to heat a can of corn or peaches, etc., as is required to heat a similar can of water.

The British thermal unit (B.t.u.) is generally employed in expressing heat quantities commercially and is the amount of heat required to raise the temperature of 1 lb. of water 1°F.

Taking a cannery with an output of 70,000 No. 2½ cans of fruit or tomatoes per 10-hr. day as an example, the following considerations will indicate the approximate amount of heat required:

Suppose that the average temperature of the tomatoes is 80°F. and that they are to be sterilized at 212°F., or the temperature rise is 132°F. One No. 2½ can of tomatoes or fruit weighs about 2 lb., or the 70,000 cans will weigh 140,000 lb. The B.t.u. required to bring the product to the sterilizing temperature are $140{,}000 \times 132 = 18{,}480{,}000$ B.t.u., if no heat is lost by radiation. One boiler horsepower = 30 lb. of steam per hour = 33,479 B.t.u. per hour. Therefore, for a 10-hr. day, 1,848,000 B.t.u. per hour or 55.2 boiler hp. would be required to heat the cans to 212°F. Normally about 33 per cent additional is required for scalding the fruit or tomatoes or an additional 18 hp. making a total minimum of 73.2 hp., or about 264 B.t.u. per No. 2½ can. To this must be added the heat units lost by radiation and the heat used for heating water and for other purposes.

In commercial fruit canneries in California having a capacity of 150,000 cans per day, the boiler capacity is usually at least 500 hp. This would indicate that the heat losses and use of steam for purposes other than sterilizing are considerable.

Relation of Steam Pressure to Temperature.—In a closed retort heated with steam the temperature will vary according to the steam pressure. Table 17 shows the relation between steam pressure and temperature.

Effect of Altitude on Sterilization.—For each increase of 500 ft. in altitude, the boiling point of water decreases approximately 1°F. The usual recommendation for the sterilization of fruits or vegetables at the boiling point at high altitude is to increase the time of sterilization 2 min. for each degree Fahrenheit below 212°. Altitude also affects the temperature of a steam retort operating at pressures in excess atmospheric pressure by amounts given in engineering hand books. The effect of altitude upon the boiling point of water is shown in Table 18.

Increase of Boiling Point by Addition of Salts.—The boiling point of water may be increased by the addition of sodium chloride, calcium chloride or other salts. This fact was made use of in the sterilization of meats and vegetables during the early years of the canning industry. It is possible to obtain a temperature of more than 240°F. by the addition of calcium chloride.

TABLE 17.—RELATION OF STEAM PRESSURE TO TEMPERATURE OF CANNING REPORT

Pounds pressure per square inch	Temperature in °F.
1	215.2
2	218.3
3	221.3
4	224.2
5	226.9
6	229.5
7	231.9
8	233.3
9	236.6
10	238.8
11	241.0
12	243.0
13	245.3
14	247.3
15	249.1

Sterilization in concentrated calcium chloride solution, however, has two objections: (1) The cans are subjected to excessive internal pressure and bursting of many may occur; and (2) the sterilized cans must be thoroughly washed to remove the adhering solution in order that corrosion of the tin plate may be prevented. The calcium chloride bath is no longer used commercially in the United States but may be used on a small scale in cases where it is not feasible or advisable to install steam pressure sterilizers.

TABLE 18.—THE EFFECT OF ALTITUDE UPON THE BOILING POINT OF WATER

Altitude in feet	Boiling point of water	
	°F.	°C. (approx.)
0	212	100
1,025	210	99
2,063	208	98
3,115	206	97
4,169	204	96
5,225	202	94
6,304	200	93
7,381	197	92
8,481	196	91
9,031	195	90

Discontinuous Open Cookers.—Until about 20 years ago the sterilization of canned fruit and some vegetables was accomplished in open wooden tanks filled with boiling water into which the cans were lowered in crates by means of a crane. This method is still in use in small canneries and in large canneries to a limited extent in the sterilization of small miscellaneous lots of fruit. The water is maintained at the boiling point by open steam jets.

Continuous Nonagitating Open Cooker.—The first improvement on the discontinuous open cooker for canning of fruits was the continuous nonagitating Dixon cooker which consists of a long wooden tank containing boiling water through which the cans placed in metal baskets are carried in by an overhead conveyer. It was in common use in California fruit canneries until about 20 years ago. The objections to this cooker were: (1) that it was very inefficient in its use of steam and wasted large amounts of heat through the evaporation of water from the sterilizer; (2) that the time of sterilization was difficult to regulate and adjust; (3) that the sterilizer occupied too large a floor space; and (4) it was complicated and costly in operation. The Dixon cooker has been practically wholly replaced by the agitating continuous open cooker.

By the term "open" the commercial canner understands a cooker which operates at atmospheric pressure. The term is somewhat misleading for the reason that the usual cooker is almost completely enclosed. It operates, however, at approximately 212°F. (100°C.).

Continuous Agitating Cookers.—The appearance of a typical continuous agitating cooker may be seen in Fig. 22. The can enters a small port hole at one end of the sterilizer and travels along a spiral inside the sterilizer. The method of conveying the cans is shown in Fig. 22. During its course through the processor it is rolled continuously and thereby thoroughly agitated.

At present most of the processors in use for fruits and tomatoes consist of a long metal tank of heavy boiler plate, inside of which is a spiral extending throughout the length of the processor and of a cylindrical reel which revolves inside the spiral, thus carrying the cans forward through the processor (see Fig. 22). The modern processors of this type are fitted with a number of inlet and outlet doors near the top of the processor in order that the process time may be varied at will. It may be filled about three-fourths full of water for processing the cans under water; or it may be used without water and the cans processed in live steam only. There are advocates of each method of operation. However, the water method of operation has one very important advantage; it permits operation at any desired temperature, such for example as 160°F. for the pasteurization of canned fruit juices. In the processing also of canned fruits in the water method of operation, it is now customary in many canneries to equip the

processor with a temperature controller and to process at a temperature 1 to 2°F. below the boiling point of water, instead of at the boiling point. Operation at the boiling point results inevitably in heavy loss of heat. It requires about 1000 B.t.u. to evaporate 1 lb. of water and only about 140°F. to heat 1 lb. of water to 210 to 211°F. Operation slightly below the boiling point also permits use of a temperature controller which will close or throttle down the steam line during the frequent intervals when cans are not entering the processor; whereas, if operated at the boiling point, use of an automatic temperature regulator is not possible and manual operation of the steam valve is necessary. Canners have found that the water method with automatically controlled temperature 1 to 2°F. below the boiling point results in very important saving of fuel. It also

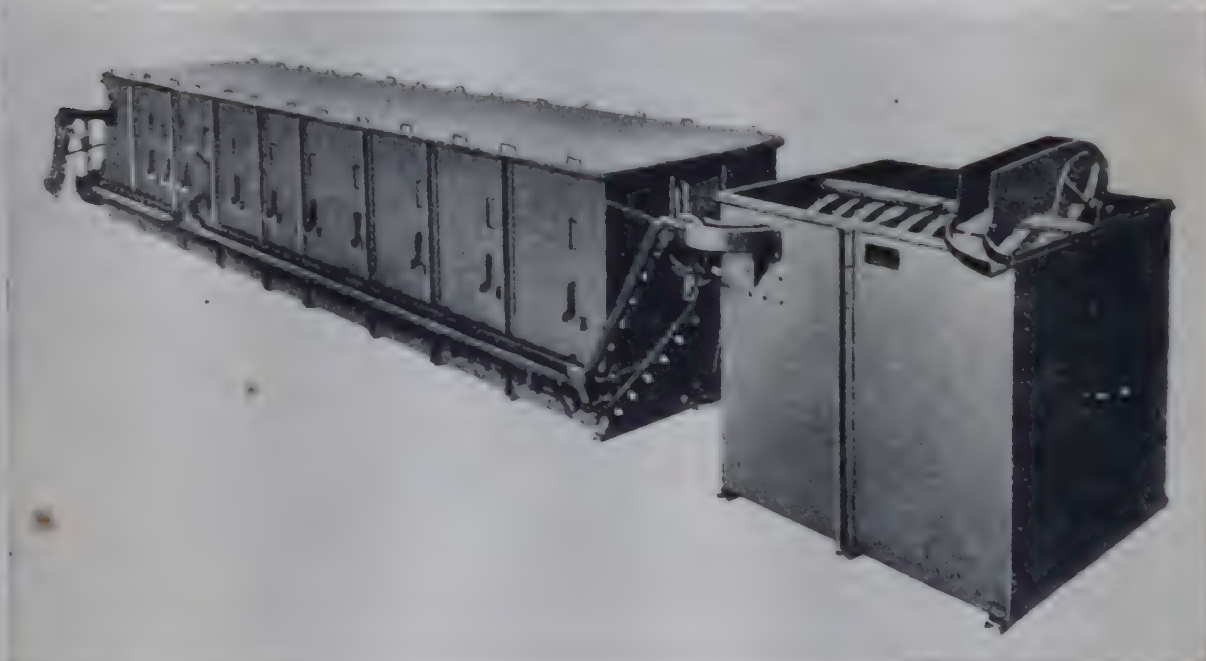

FIG. 22.—Continous agitating cooker for fruits and tomatoes. (*Courtesy Food Machinery Corporation.*)

results in far less escape of steam into the cookroom and thus in better working conditions.

Formerly most of the processors were rectangular in cross section; then for a time many were cylindrical in form and of circular cross section. The present trend is toward a processor shell the lower half of which in cross section is a half circle and the upper half, rectangular. This permits ready access by lifting off the flat lid, in contrast with the cylindrical processor which is very difficult of access. This is important, as it is usually necessary several times during the season to open the processor to remove cans that have become crushed between the reel and spiral and thus have brought operation to a standstill.

The capacity of the processor ("cooker") in cans per minute varies, naturally, with its length and diameter and with the length of process.

The output in cans per minute is found by dividing the number of cans held by the processor with reel completely filled by the length of the process in minutes. Thus, the largest processor for No. 2½ cans holds 3,105 cans. With a 20-min. process it will "turn out" 155 cans per minute. In actual practice, however, the maximum holding capacity of the processor is not used, as the length of process is controlled by use of portholes for entry or emergence of the cans at various points along the side of the processor, rather than by using the entire length of the processor and governing the length of process by varying the speed of rotation of the reel. Thus a can given a 10-min. cook would traverse only half the distance in the processor traveled by one given 20 min. processing. Normally, the syruping machine, can-closing machine, exhaust box, and processor are synchronized in operation, in order that the cans may move through each at a uniform rate.

Discontinuous Nonagitating Retorts.—To a canner a "retort" signifies an autoclave or closed processor in which the cans are heated in steam under pressure. In an open processor using water as the heating medium the maximum temperature attainable is 212°F.; whereas in a retort, temperatures of 240 to 260°F. or higher are readily attainable.

The simplest form of retort is an upright or horizontal heavy steel cylinder in which the cans are placed in crates and which is operated with steam under pressure. In California the horizontal retort is the more popular, but in eastern canneries the small upright retort, which is sunk below the floor level, is in common use. The advantage claimed for the horizontal retort is that cans may be placed in crates or small steel cars which can be quickly and easily placed on a steel track in the retort. Usually both ends of the retort are fitted with heavy swinging doors, so that after sterilization the cars of sterilized cans may be removed from one end of the retort while loaded cars may be entered at the opposite end. The appearance of such a retort is shown in Fig. 24. The usual size is approximately 60 in. by 10 to 20 ft.

The upright retorts are used in a battery above which is a traveling crane, usually operated by air pressure. Cans are filled into circular crates which are lowered into the retorts. It is claimed for this style of retort that, owing to the fact that only a small quantity of material is required to fill it, the exhausted or the sealed cans are not allowed to stand very long without sterilization and hence do not have an opportunity to cool appreciably before sterilization.

Retort Operation.—Three important methods of heating retorts are in use, *viz.*, steam, steam plus air, and water plus air. The first is used for canned products to the practical exclusion of the other two methods. The steam-plus-air and water-plus-air methods are used for glass containers; owing to the presence of air the extra pressure is required to hold

the lids in place on glass containers. In California use of the steam-plus-air method is prohibited by the State Board of Health, owing to the difficulty of securing uniform and rapid heating of the contents of the retort by its use. While its use may be permitted in some other states, the writer strongly advises against it for the reasons given, and he recommends instead that water plus air be used, as later described.

It is essential in the pure steam method of operation to vent the retort generously through vents in the top of the retort during the "com-

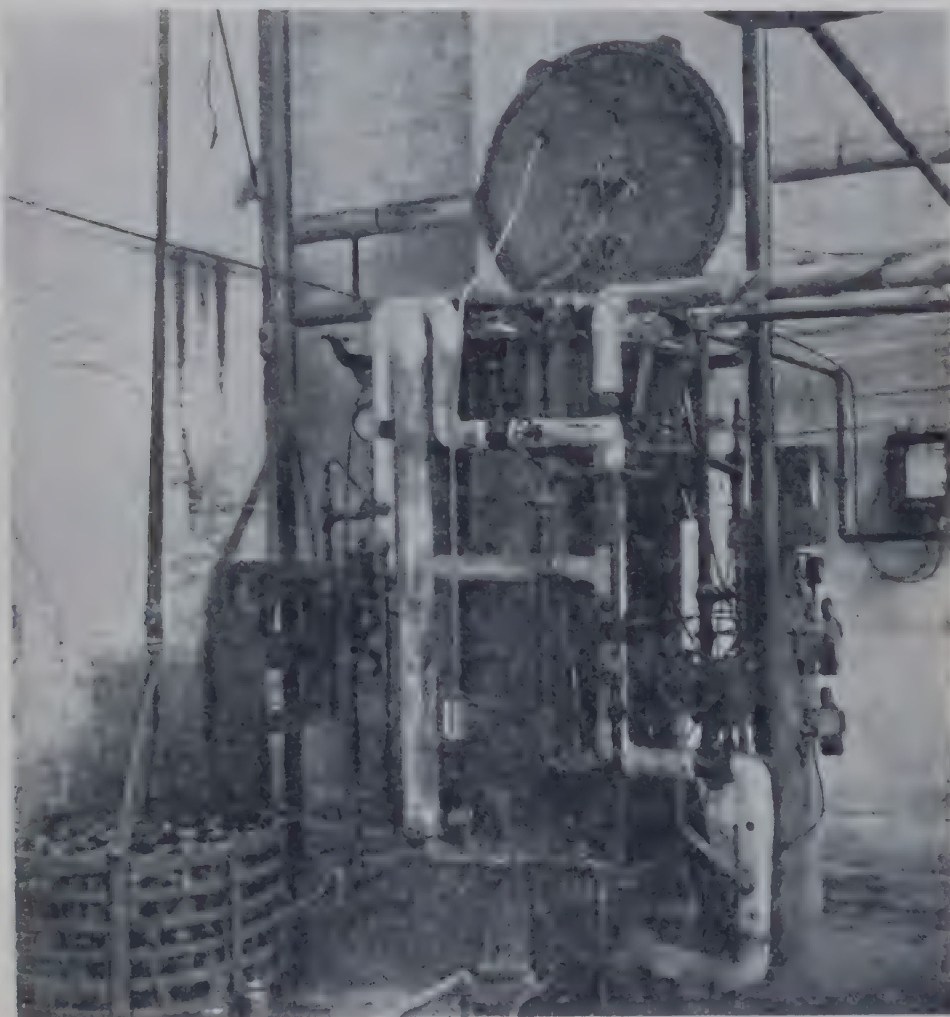

FIG. 23.—Vertical retort equipped with thermocouples for heat-penetration studies of Parcell and Ford.

ing-up" period in order to remove all entrapped air; otherwise heating will not be uniform. After the retort has attained operating temperature the thermometers and pressure gauges should "agree," *i.e.*, if the operating temperature is 240°F., the pressure gauge should show slightly more than 10 lb. pressure. A pressure much higher than 10 lb. at 240°F. indicates the presence of entrapped air.

After retort temperature is attained, the vents may be closed and only the small pet cocks ("bleeders") left open to allow as much steam to escape as is necessary to remove noncondensable gases entering with the

steam and to promote circulation. After the cans have attained retort temperature, they tend to maintain a constant temperature throughout the retort, so that the presence of air is then less objectionable than during the coming-up period.

The most potent cause of irregularity in temperature during the coming-up period is condensation of the steam on the cans near the point of entry of the steam. In other words the steam as it enters early in the heating period gives up its heat to the relatively cold cans and is thus condensed to liquid water. This leaves that much less steam to rise and heat the cans above.

It is extremely important that the pocket surrounding the bulb of the thermometer be thoroughly vented at all times in order that live steam will flow around the bulb, which can then and only then respond to the true retort temperature.

The location of the bulb of the temperature control device is of importance. When placed in the bottom of the retort near the steam inlets, it responds to the temperature of the surroundings there, and as these reach retort temperature sooner than the region near the top of the retort, the controller may close the steam supply valve before the cans in the upper part of the retort have attained retort temperature. In this manner their attainment of retort temperature may be seriously delayed, and consequently they may receive insufficient processing. It is customary to locate the bulb in a pocket in the wall of the retort about midway between the top and bottom.

In the processing of glass containers the retort is filled with water, the retort being equipped with an overflow valve, or in other manner protected against bursting because of excessive pressure attained by expansion of the water and condensation of steam. Steam is admitted to heat the water, and air is admitted to mix the water and maintain the additional pressure required to hold the lids of the jars in place. The steam and air should be mixed outside the retort in order that the air may be heated before entry and that "rumbling" will be minimized. The top of the retort should be well vented. The water level should be well above the topmost jars, otherwise, as Parcell's data showed, the jars resting in air plus steam, only, will drop below retort temperature. A sight gauge (glass tube) on the side of the retort is very useful for showing the water level. Instead of venting the thermometer pocket, Parcell recommends use of forced circulation of water through the pocket, attained by connecting the pocket to the steam line by a small pipe.

Parcell found that the water-plus-air method gave much more uniform heating of containers at different levels in the retort during the coming-up period than was possible with steam alone or with steam plus air. It required more heat units, naturally, owing to heat required to

bring the water to retort temperature. The air not only provides the extra pressure required but also stirs the water and thus prevents local overheating or underheating. It is usual practice to admit the air and steam through a perforated pipe cross in the bottom of the retort; but Parcell found that heating and mixing are more satisfactory by a method patented by him under *U. S. Public Service Patent* 1,708,105, April, 1929. It consists in mixing the air and steam outside the retort and admitting the mixture through three tangentially placed, muffled jets, which give a vigorous rotary motion to the water. Air rising from the jets gives additional agitation. This hookup gives very rapid and uniform heating with very little noise and vibration ("rumbling").

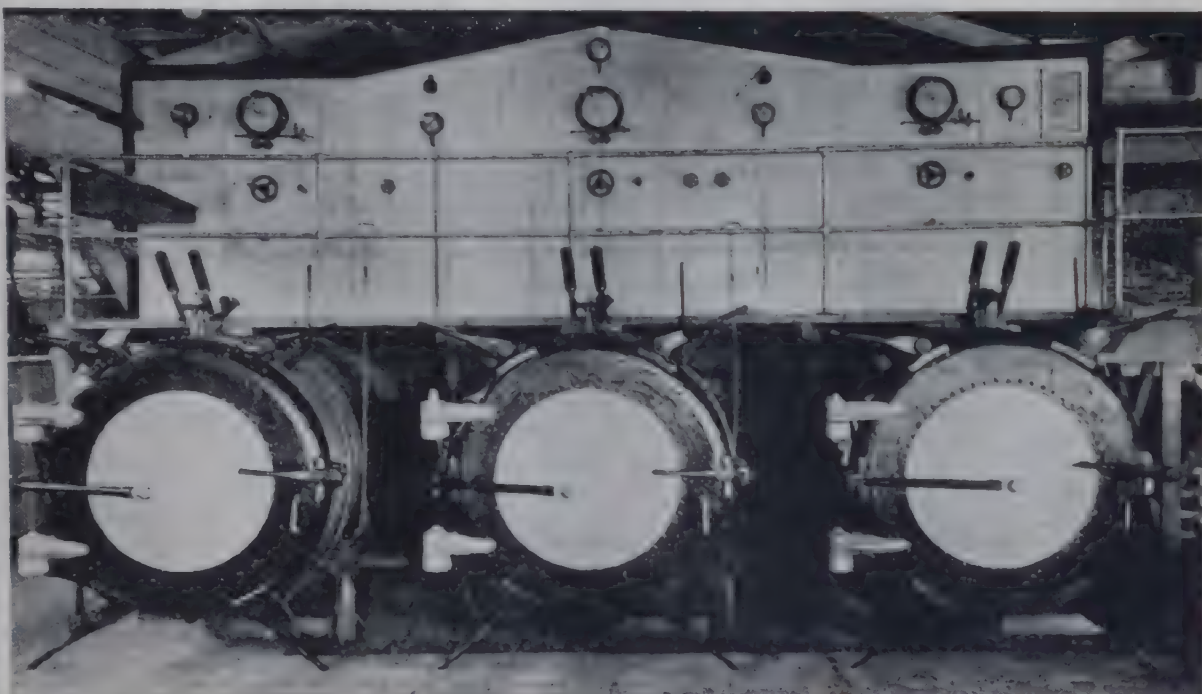

FIG. 24.—Horizontal retorts for spinach, peas, asparagus, and other vegetables. Equipped with temperature control and recording instruments. (*Courtesy Foxboro Instrument Company.*)

When the processing period is completed, rapid cooling of the contents is necessary to arrest cooking. Cold water admitted directly against glass containers would break them; releasing the pressure would allow the lids to be forced from the jars by the internal pressure of their contents. Consequently, in cooling glass jars it is advisable to temper the ingoing water by heating it with steam to a safe temperature and to gradually drop its temperature as cooling progresses. At the same time air is admitted to maintain sufficient pressure to prevent loss of lids. The air rising through the water mixes it and prevents "blanketing."

In cooling cans it is not necessary to temper the water; cold water may be admitted directly. However, it is necessary for large cylindrical

cans, and advisable for medium size and square asparagus cans, to provide air pressure sufficient to prevent "buckling" of the cans.

Records of Processing.—It is of great importance to the canner to mark the cans of each retort load with an identifying code mark in order that if spoilage or other difficulty develops later the cans of the affected lot can be segregated. In California such coding is compulsory and under State Board of Health supervision and in addition the canner must equip each retort with a recording thermometer. The temperature curve for each load is recorded on the thermometer chart and is given an identifying number in order that it may be correlated with the lot code on the cans. The chart is filed with the State Board of Health for future reference.

Temperature Control and Recording.—In up-to-date well-equipped canneries the temperature of retorts, of open cookers, and of exhaust boxes is usually controlled automatically. Not only does the automatic controller give much closer control of temperature, but it also results in an important conservation of steam and reduced labor cost.

Controllers are of two general types, *viz.*, self-actuated and indirect controlled. The former does not give very close control and, therefore, is not suitable for use on retorts, although satisfactory for exhaust boxes and certain other equipment where closely controlled temperature is not essential. One form of direct-acting regulator consists of a metallic rod fixed at one end and attached to a lever arm at the other end. As the rod expands with rise in temperature, it operates a valve to close the steam line, and as the temperature drops, contraction opens the valve.

Most controllers used in canneries are of the vapor-tension, air-controlled type. The instrument usually consists of a temperature-measuring element consisting of a metallic bulb half filled with a low-boiling liquid, such as ethyl ether, the bulb being connected by a small metallic tube to a helical metal coil in the instrument case. The free end of the coil is attached to a pen arm fitted with an ink-filled stylus resting on a circular chart. The ether or other liquid gives off vapor in proportion to the temperature of the retort, causing a corresponding rise in pressure in the vapor in the bulb, connecting tube, and helical coil, which in turn expands or contracts ("coils" or "uncoils") and moves the pen arm and stylus across the chart correspondingly. The chart is rotated slowly by a clock mechanism giving on the chart a complete record of heating, holding, and cooling the retort load. Formerly the bulb, the connecting tube, and the helical tube were filled completely with fluid (usually mercury); but such an instrument is sluggish in action and is seriously affected by the temperature outside the retort and on this account often inaccurate. On the other hand the vapor-tension instrument is not subject to such

error, since pressure in the line is that at the liquid-vapor interface in the bulb.

The pressure in the bulb of the temperature controller also actuates the temperature-controlling mechanism, usually by means of an air-controlled steam valve as shown in Fig. 25. Briefly, the mode of operation is about as follows in one typical instrument: Compressed air is admitted to the instrument from a compressed air reservoir through a reducing valve set at about 20 lb. pressure per square inch. The small tube carrying the compressed air is closed when operating temperature is attained; when the temperature drops, the vapor pressure in the control bulb drops, and

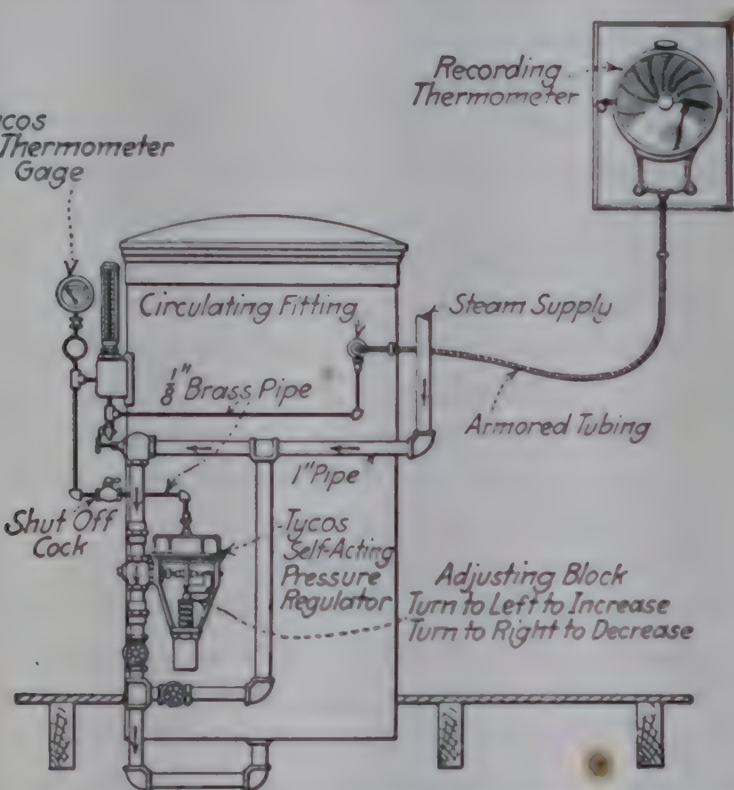

FIG. 25.—Temperature-regulating equipment and recording thermometer on a vertical retort. (*Courtesy The Taylor Instrument Company.*)

the helical coil in the instrument contracts opening a "flapper valve" over an orifice in the air line, allowing the air pressure to operate a steam valve in the main steam line to the retort. As temperature is again attained, the vapor pressure increases in the bulb, expands the helical coil which in turn closes the flapper valve of the air-control system and hence closes the air line to the steam-control valve, which is then closed by a powerful spring. Details of the mechanism vary with different makes of air-controlled instruments, but all make use of compressed air to either open the steam valve (direct acting) or to close that valve (reverse acting). The direct-acting valve is the more desirable because, if for any reason the control system should fail to operate, all that can happen is that the steam valve is closed by the spring, and processing ceases; whereas, in the case of

a reverse-operating instrument a breakdown would leave the steam valve open, with the result that the pressure might rise in the retort to the bursting point.

Electrically operated temperature instruments are now coming into use for control of temperature in processors. A control bulb of the vapor-tension type previously discussed is inserted in the retort or other processor. Vapor pressure operates a helical coil which in turn makes and breaks contact with an electrical circuit containing a relay and a solenoid operated or motor operated valve in the steam line. The controller is sensitive, accurate, and except for interruption in power service, dependable. It can be made to operate a signal light or other signaling device.

For additional details of temperature measurement and control see Foote, Fairchild, and Harrison; Parcell; and booklets of the various instrument companies such as the Foxboro Company, Tagliabue Company, Taylor Instrument Company, Brown Instrument Company, the Bristol Company, and Leeds and Northrop Company.

Process Times and Temperatures.—The National Canners' Association has issued a bulletin (26-L) of very great importance to the canners of nonacid vegetables as it gives for different sizes of cans processing temperatures and times for different sizes of cans of all the important nonacid canning vegetables. Owing to its length, it is not practicable to reproduce the table in this book. Many of the recommended processes are given, however, in the chapter on vegetable canning.

The bulletin makes the following additional recommendations. Cans, except those sealed under mechanical vacuum should be sealed at not less than 130°F. in order to prevent undue strains on the can and to maintain a concave appearance after processing. Each retort should have: (1) an automatic temperature controller; (2) an indicating mercury thermometer; (3) a recording thermometer; (4) a pressure gauge (preferably of compound type); (5) a vent of at least $\frac{3}{4}$-in. inside diameter to be used during the coming-up period; (6) a $\frac{1}{8}$-in. bleeder in each thermometer pocket; (7) at least one $\frac{1}{8}$-in. bleeder in the top of the retort; (8) a steam by-pass around the controller to permit rapid rise in temperature; and (9) a perforated steam line entering the retort at the bottom beneath a perforated steel plate. The recording thermometer should have a range of 170 to 270°F., and the scale divisions should not exceed 2°F. The pressure gauge should have a range of 0 to 30 lb. and be graduated in 1-lb. divisions. At least two-thirds of the length of the bulb of the controller-recorder should extend into the principal chamber of the retort.

The blowoff vent ($\frac{3}{4}$ in. or larger) should be open during the "lag" or coming-up period. The bleeders should be open throughout the process. There should also be an adequate drain in the bottom that can be used as a vent as well as drain. All cans should be coded.

A high temperature such as 248°F. requires less time than a moderate temperature such as 240°F., but it also damages the product more severely in case of a few minutes overprocessing.

The character of the data presented in Bulletin 26-L may be seen from that given for white asparagus. The process time at 240°F. for 8-oz., No. 1, No. 1 tall, No. 2, No. 1 square, No. 2½ square, No. 2½ round, No. 1½ flat, and savoy tip cans is 20 min. in all cases; and at 248°F. it is 12 min.

Agitating Discontinuous Pressure Sterilizers.—This type of sterilizer has been developed in the sterilization of milk. It has been found that milk tends to scorch and curdle unless it is agitated during sterilization under pressure. The cans are placed in a cage inside the retort and the cage revolved during sterilization, keeping the cans constantly in motion and thoroughly agitated. The writer is not aware that this sterilizer is used extensively for other products, although it would be undoubtedly of service in the sterilization of some vegetables.

Continuous Agitating Pressure Sterilizers.—During the past few years cannery machinery companies have experimented in the manufacture of continuous agitating sterilizers built on the same general principle as the open agitating cooker. The principal difficulty has been the one of admitting the cans to the retort and removing them after sterilization continuously without affecting the steam pressure in the retort, but this difficulty has been overcome by the construction shown in Fig. 26. It has been proved by Bigelow and others that a very much higher temperature and a correspondingly shorter time can be employed with the agitating continuous cooker, for the reason that agitation prevents overheating of the product in contact with the tin. This retort is particularly desirable for corn and spinach since it greatly increases the rate of heat penetration, thereby making a shorter process time possible and reducing danger of overcooking correspondingly. Its principal disadvantage is its high initial cost.

Cooling after Sterilization.—As soon as the contents of the can have been thoroughly sterilized it is essential that the can and contents be cooled immediately. It is customary in most canneries to stack the cans in large piles after sterilization, and if the contents of the cans have not previously been cooled sufficiently, cooking may continue for several days in the center of these stacks. This results in the development of dark color in peaches and pears, in the scorching and darkening of tomatoes and other vegetables and in the development of "flat sours" in vegetables through the growth of thermophilic spore-bearing bacteria which survive the usual commercial sterilization process.

The cans should not be cooled to too low a temperature for the reason that they will remain wet and become rusty. A temperature of 110 to 115°F. is high enough to dry the cans but not high enough to cause injury

to the contents. Cooling is accomplished by sprays of cold water or by passing the cans through a tank of running cold water. In either system a large amount of water is needed. Cooling under sprays makes much more efficient use of the cooling water, since it takes advantage of the great amount of heat absorbed from the cans and contents by evaporation of water from the surface of the containers. This method of cooling has proved very successful in cooling canned orange juice, where extremely rapid cooling is imperative. The spent cooling water may be cooled by tower and used repeatedly.

A cooling device of the same general design as the continuous agitating sterilizer is shown in Fig. 22.

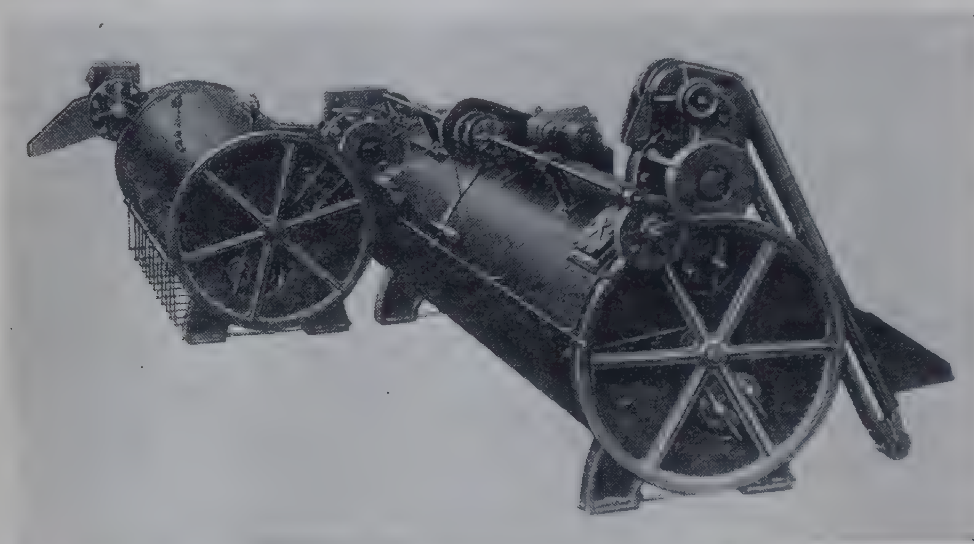

Fig. 26.—Continuous agitating pressure sterilizer (retort) and cooler. (*Courtesy Food Machinery Corporation.*)

The cooling process is completed by stacking the cans overnight in an open court, usually in such a manner that air currents may pass freely around the cans.

Testing Vacuum of Cans.—It is desirable that the canner have accurate information upon the degree of vacuum in the cans after sterilizing and cooling because faulty sealing of the cans is very quickly detected by vacuum test. The simplest form of tester consists of a dial gauge equipped with a sharp, hollow tube and large, soft, rubber gasket. The sharp tube is inserted in the lid of the can by pressure and the entrance of air prevented by the heavy rubber gasket. The vacuum may then be instantly read from the dial.

The appearance of such a can tester is shown in Cruess and Christie's "Laboratory Manual of Fruit and Vegetable Products." Another excellent vacuum tester is a bell jar (containing the can under water) which is subjected to a gradually increasing vacuum by means of a hand pump. Poorly sealed cans emit bubbles of air. When the vacuum inside the can and in the bell jar become equal, the head of the can bulges

slightly. This vacuum tester is valuable in making frequent observations on experimental cans because the cans are not injured. Recently a simpler and more rapid device has been introduced by the American Can Company and National Canners' Association. A rubber washer is placed on the can. On the washer is placed a funnel attached to a vacuum line. Vacuum is applied until the lid of the can "flips." The corresponding vacuum is read instantly on a gauge.

Canners also test the cooled cans by tapping with a short steel rod. Imperfectly sealed cans or "leakers" give forth a "hollow" sound and perfectly sealed cans a "flat" sound. The method is simple, extremely rapid, and surprisingly delicate. An experienced workman rarely fails to detect faulty cans by this test.

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CHAPTER XI

CANNING OF FRUITS

The commercial canning of fruits has increased rapidly during the past 30 years, particularly on the Pacific coast of the United States and in Hawaii. Australia also is vigorously developing its fruit-canning industry, in some cases under government subsidy and supervision.

General.—The use of fruit varieties especially suited to canning and the careful observance of established commercial size and quality grades are the two most important fundamentals in the successful commercial canning of fruits. Ungraded canned fruit is unattractive in appearance, is uneven in color, texture, and maturity, and is not a product that will command a high enough price to return a reasonable profit to the canner and the grower.

The fruit must be gathered at the proper stage of maturity for canning, *i.e.*, it usually should not be so ripe or so soft as that for eating fresh, yet it should have attained the flavor characteristics of the ripe fruit.

The fruit should be picked carefully and transported to the cannery quickly without bruising.

Boxes must be clean and must not be permitted to become moldy and heavily impregnated with fermented and soured fruit juice or pulp.

A clean factory operated with strict observance of the fundamental principles of sanitation is essential to the production of canned fruits of high quality.

Canning Season for Fruits and Vegetables in California and Hawaii.—The fruit canning season starts in California with cherries in May and ends with tomatoes in November (see Fig. 6).

PEACHES

(Prunus Persica)

A larger quantity of peaches is canned than of any other single fruit, although pineapple is now a close rival. Its delicate flavor, which persists after canning, its firm texture, which permits sterilization without disintegration, its attractive appearance and moderate price have combined to give the peach its present popularity.

Varieties of Peaches for Canning.—Peaches for canning by usual procedure should be of large uniform size, of symmetrical shape, of yellow color, of close tender fiber, not coarse or ragged, and of good cooking

quality, *i.e.*, should retain their form, size, flavor, color, and aroma during sterilization in the can. The pit should be small in order to give thick halves that do not flatten during heating. The fruit should ripen evenly from the surface to the pit and should not be softer at the pit than at the surface. Some varieties retain their fresh flavor well or improve in flavor on heating after canning; others acquire a disagreeable flavor on heating, this being particularly true of some freestone varieties.

In general the firm, yellow clingstone varieties grown in California for canning possess the qualities enumerated above, whereas most of the freestone varieties lack one or more of these desired characteristics. Most of the varieties of clingstones used for canning are inferior to most freestones in flavor. On this account in recent years, consumer interest in canned freestone peaches has greatly increased, and if canners properly take advantage of this trend, it should be possible to greatly increase the pack of canned freestones. Some canners are featuring a "ragged" pack of freestone peaches, advertising the fibrous appearance of the freestone as a virtue. Its lack of flavor is the clingstone's chief defect, a fact that undoubtedly accounts for much of its loss in popularity in comparison with the increase in popularity of its chief competitor, canned pineapple.

Three types of canning clingstone peaches are grown in California, *viz.*, the Tuscan, an early variety, the Midsummer group of several varieties, and the Phillips, a late variety. The Midsummer varieties are considered superior to the Tuscan and Phillips in canning quality.

The Tuscan (sometimes called Tuskena) is an early, large variety, ripening in California from about July 15 to about Aug. 1. Its principal canning season follows immediately that of apricots. It has a rich flavor, and its texture after canning is satisfactory. Its defects enumerated below, however, are so serious that it is rapidly becoming obsolete as a canning variety. Its flesh near the pit is red in color, a desirable property in a fresh fruit; but on heating, the red color becomes an unattractive brown. The pit is very large; consequently, after pitting, the halves are thin and become flat in outline on heating. Many of the pits split, making it difficult to halve and pit the fruit economically, without marring the flesh. It is the only important early-ripening variety, and there is great need for another early variety of better quality to replace it. Plant breeders and horticulturalists are attempting to develop such a variety by crossing and selection.

Four to six weeks elapse after the close of the Tuscan season before the opening of the Phillips season. Consequently, canners require Midsummer varieties in order to permit a long canning season. There are many such varieties available. Of these the Paloro (also spelled Pelora) is one of the most important. It is of large size, of rich flavor, firm, of small pit, and symmetrical shape. The tree is subject to rust, a fungous

disease, and much of the fruit drops as it approaches maturity. Aside from these defects it is a very good variety; being decidedly superior to both the Tuscan and Phillips in flavor and general canning quality.

The Hauss resembles the Tuscan somewhat in outward appearance and the Phillips in canning quality, although much superior to the latter in flavor. The skin carries considerable pink color.

The Sims ripens toward the end of the Midsummer season. It is large in size and gives a large proportion of Fancy and Choice grades. It is of good canning quality.

The Orange is an old Midsummer variety, once popular for canning, but at present available in small quantities only. It has a highly colored skin and yellow flesh. The pit is large.

Other Midsummer varieties are the Walton, Libbee, and Peaks.

The Phillips cling is a late variety, ripening in September. It ripens over a longer period than the Midsummers and may be left on the tree longer than other varieties without deterioration in quality. The skin is usually free of pink color, and the flesh is deep yellow rather than orange-yellow. It is very firm, ships well, and cans well. However, it is lacking in flavor and very variable in size, much of the fruit being too small for canning. It is decreasing in popularity in comparison with the Midsummer varieties.

The Levi is a very late clingstone of poor flavor, large pit, and poor color. The Sellers is a late cling used in Australia and has been grown experimentally in California, where it is not considered of so desirable canning quality as the better Midsummer varieties.

Several freestone varieties have been used for canning. Of these the Lovell is one of the best for canning, owing to its firm, fine texture, yellow color, and pleasing flavor. It retains its flavor well in canning.

The Elberta is grown in California and elsewhere primarily for table use. It is of large size; the skin is highly colored; the flesh is deep yellow except near the pit where it is red. It is ragged in appearance but of very pleasing flavor after canning. The J. H. Hale resembles the Elberta in color and canning quality.

The Muir is the most important of the varieties used in California for drying. Its dry, mealy texture makes it unsuitable for canning. The Crawford and Salway have been canned but are not very satisfactory for the purpose.

The shipping varieties of peaches grown in Georgia have not been found very suitable for canning purposes, except for pie fruit, because the color is not desirable and because the fruit softens badly during canning.

Of the varieties adapted to the eastern United States, the Elberta seems to be the most popular for canning.

Picking and Shipping Peaches for Canning.—Peaches for canning purposes should be picked when of maximum size and at the firm ripe stage of maturity. Great care must be used in order to avoid bruising. The lug boxes should not be overfilled, and the ends should be protected by cleats so that the fruit will not be crushed when the boxes are stacked in the car or truck.

It is customary to allow the fruit to stand in the orchard during part of the night to cool before shipment, in order to minimize spoilage in transit. It is necessary to make several pickings of the fruit so that all of it may be gathered at the most desirable stage of maturity. In California the Canners League usually maintains a force of inspectors at the shipping points in the peach districts. Samples of several boxes of fruit are taken from each load and are sorted and graded for size in order to determine whether the fruit meets the League's requirements for No. 1 canning fruit. Such fruit must be at least 2⅜ in. in diameter, free of blemishes, of proper maturity, and of good canning quality. Inferior fruit is rejected.

Delay after picking results in overripening and in deterioration of flavor, and if the fruit is to be held several days, it should be placed in cold storage at 32 to 36°F.

Receiving.—On receipt at the cannery, the fruit should be graded roughly according to maturity and variety by segregation of boxes. The receiving room should be cool and well ventilated.

In some canneries a large sample of each shipment of fruit is carefully sorted to determine the relative amounts of the different grades present, and the grower is paid accordingly.

Cutting and Pitting.—The first operation in the canning process is that of halving and pitting. This work is done by women by hand or by machine.

Tables.—Many different styles of cutting tables are used. One type in use by one of the largest canning organizations in California consists of a long table equipped with a belt which delivers to the cutters the desired amount of fruit, usually one lug box (40 to 50 lb. of fruit) at a time. A second belt beneath the cutting table carries away the pits and culls. In front of each cutter are from two to three dishpans. In one of these is placed the firm ripe fruit, in another the green fruit, and in the third the overripe and pie fruit. Special tables are used for pitting by machine.

In other canneries the fruit is delivered to the cutting tables by hand trucks, but this method of delivery is expensive and often results in confusion. In one large California cannery the cutting tables are equipped with three belts, one to deliver the firm fruit to the peeling machine, one to care for the pie grade of fruit and one to carry away the pits. In small canneries the cutting table is not equipped with belts; and the pits and

refuse are thrown into buckets or dishpans, which are periodically removed by the men who deliver the fresh fruit to the cutters.

Cutting and Pitting by Hand.—A fruit-cutting knife is used to cut the peach around the suture from the surface to the pit. A spoon-shaped knife is then inserted from the stem end of the peach and with this instrument the flesh is cut from the pit. Freestone varieties are halved, and the pit is then easily removed with the cutting knife.

The women who do the cutting also trim the fruit and do a reasonable amount of sorting for quality. Thus, pie-grade fruit is segregated from the better grades to some extent.

Cutting and pitting of peaches are the most expensive operations in the canning of this fruit. In one large plant in the San Joaquin Valley, 250 cutters were necessary, while only 50 workmen were required for filling the cans and 150 for all other operations. Approximately 90 tons of fruit was canned per 10-hr. day with this force of 450 employees. The ratio of cutters to other workmen will vary with the variety and size of the fruit and with the amount of automatic machinery employed.

It is essential that the cutting operations be directed by capable forewomen who are thoroughly familiar with fruit varieties and fruit grades.

Cutting and Pitting by Machine.—Recently machines for pitting clingstone peaches have been so greatly improved in design that they have displaced hand pitting in many canneries. In using one form of pitter (the Pacific) the peach is forced by hand and rotated between knives which face each other and are so spaced that as the peach is forced toward the pitting blade the fruit is cut to the pit. The fruit is brought into position in contact with a crescent-shaped pitting blade. The machine is then tripped, setting in motion gears that rotate the pitting blade, which in turn carves its way around the pit. The pit and two halves drop from the machine. The pits are separated from the halved fruit by suitable screens, and the halves are carried to the lye peeler by belt conveyer. Imperfectly pitted halves ("split pits") are taken to a hand-operated pitting machine or are pitted by hand (see Fig. 29).

In the second form of pitting machine (Federal) the fruit is cut in half by rapidly revolving buzz saws, and the halved fruit with adhering pits are conveyed to tables where women place the halves in a second machine which removes the halved pits by a mechanically operated crescent-shaped knife.

The output of the mechanical pitter is about four times that of a woman pitting by hand. An output of 15 to 20 lug boxes, of about 45 lb. of peaches each, per hour is readily attainable by machine. The "workmanship," *i.e.*, smoothness and cleanness of pitting, of the machine is good, although some canners believe that yields by hand pitting are higher.

The machines are usually rented rather than sold outright to the canner.

Peeling.—In California the halved peaches are peeled by treatment with hot lye solution as described in Chap. VI. The concentration of the peeling solution is normally between 1 and $2\frac{1}{2}$ per cent and the length of application 30 to 60 sec. Green fruit requires a stronger solution than ripe fruit. In the Dunkley peeler the hot lye is applied as a spray to the fruit as it is carried through the peeling compartment on a metal-cloth conveyer. The lye is circulated by pump and is heated by steam. In another well-known peeler the peaches are carried through a tank of boiling lye solution by a revolving drum.

The concentration of the lye is maintained by adding concentrated lye solution or the dry flake caustic (flake $NaOH$); such addition is necessary because dilution and neutralization of the lye reduce its strength rapidly. The operator judges when lye addition is needed by observing whether the fruit is well peeled or not. In many plants the solution is titrated frequently with standard hydrochloric acid, and an attempt is made to maintain a fairly constant concentration; in others the desired concentration is maintained by an automatic controller dependent on the conductivity of the solution, which varies with the $NaOH$ concentration. Ordinary 60-cycle 110-volt current is used in the controller circuit. It passes through the solution between iron electrodes and opens a magnetic valve which admits concentrated $NaOH$ when the concentration drops below that for which the controller is set.

If the solution is too strong, too much of the flesh is removed, entailing excessive loss in weight and decrease in diameter of the fruit. If it is too weak, the fruit is imperfectly peeled and much hand trimming becomes necessary; hence the advisability of close control of concentration.

The lye tank should be emptied at the end of each day's operations and refilled with fresh solution.

The fruit should be carefully sorted as to ripeness before peeling since green fruit is much more difficult to peel than ripe and should receive a stronger solution.

Washing.—The Dunkley patents for many years prevented the use (except in the Dunkley peeler) of sprays in washing the lye-treated fruit to remove skins and excess lye. At present, however, the use of sprays is general. The fruit is either spray washed in a metal-cloth draper or in a revolving metal drum. The sprays must be ample in volume and of high pressure in order to "cut" the lye softened tissue from the pit cavities and outer surface. If this tissue is not removed, it becomes brown or gelatinous in the canned product. Severe washing also is necessary in order to remove adhering lye completely; if this is not done, the surface darkens rapidly.

Research conducted by P. J. Quin in this laboratory showed that dilute (0.25 to 0.50 per cent) hydrochloric acid or dilute citric acid could be used to advantage as a rinse following washing. The dilute acid increases the acidity at the surface and thereby inhibits browning. The chloride ion is also a powerful oxidase inhibitor; hence hydrochloric acid is a much more effective preventative of darkening than is citric acid. Some canneries now use such a rinse, following the blanching operation.

Blanching.—From the washer the peeled peaches are usually heated a short time in hot water or steam to remove final traces of lye and to partially inactivate the oxidase responsible for browning of the surface. P. J. Quin, previously mentioned, found that a temperature of at least 175°F. is necessary to cause much oxidase inactivation in the usual short period (1 to 2 min.) of blanching; and that about 10 min. was required to heat the half completely through. Often when halved, peeled peaches are sliced for packing in that form, unattractive crescent-shaped brown areas will be evident at about 1 to 2 mm. below the surface. The browning is located at the line of demarcation between the flesh that has been heated sufficiently to destroy the oxidase and the unheated flesh near the center of the half. It is due to oxidasic browning and appears only after the fruit has stood for a considerable period. Prevention lies in either heating the fruit completely through in blanching; replacing blanching with an acid rinse; or canning promptly after blanching.

Amount of Lye Used.—The amount of lye required varies from about 6 to about 15 lb. per green ton of fruit, according to type of peeling machine and the variety of peaches used. In one large cannery about 7 lb. of 95 per cent sodium hydroxide were required for each ton of peaches peeled.

Steam Peeling.—Some varieties of peaches, especially thoroughly ripe table varieties, can be peeled by placing the halved and pitted fruit on trays and subjecting the fruit to live steam for several minutes. The peels can then be slipped from the fruit with the fingers.

Loss in Peeling.—The loss in weight of fruit in lye peeling of peaches varies greatly. In a test made by the author, the loss was approximately 12 per cent according to data obtained upon the spray type of lye peeler. Hand peeling results in a greater loss, estimated at about 20 per cent.

Sorting.—The peeled fruit passes from the lye peeler or blancher to a broad rubber or woven-wire belt before which are sorters who remove fruit which is blemished, broken, badly peeled, or improperly washed. The fruit in prime condition travels by conveyer to the grading machine, whereas pie fruit is carried by belt to the canning room and does not pass over the grader. The women at the sorting belt can sort fruit at a much lower cost and more efficiently than can those engaged in placing the fruit in the cans. If the fruit requires it, it is trimmed by hand.

Grading.—Usually five or six grades for size are made by means of the grading machines described in Chap. VII. The smallest fruit is usually placed in the pie grade, and the largest size is often sliced before canning. The largest and most perfect fruit forms the Fancy grade, whereas fruit of smaller sizes is represented by Choice, Standard, Second, and Pie grades, respectively. However, these grades depend more upon appearance than upon size. The Pie grade, in addition, comprises blemished fruit, overripe fruit, and green fruit. Most canners consider Fancy-grade peaches as those $^{76}/_{32}$ in. or greater in diameter, Choice-grade peaches $^{64}/_{32}$ in. or above, and Standard-grade peaches $^{56}/_{32}$ in. or above, provided the fruit

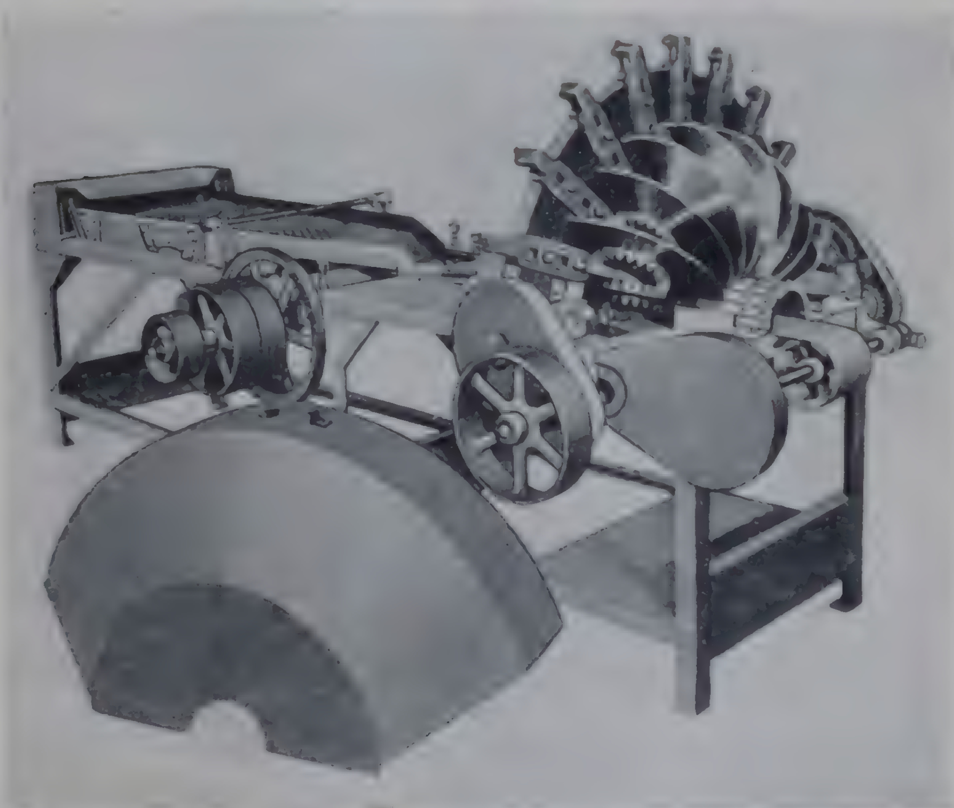

FIG. 27.—Peach-slicing machine. (*Courtesy Food Machinery Corporation.*)

meets the requirements of these grades in other respects. Second and Pie grades are not graded for size (see Fig. 12 for appearance of a peach grader).

Slicing.—There is an increasing demand for sliced peaches for dessert purposes, ordinarily canned in No. 1 tall cans. There is also a tendency at the present time to slice a great deal of the pie grade of fruit in order to make it more attractive and more uniform in appearance.

The peach-slicing machine consists of several circular revolving knives, beneath and against which the fruit is carried by means of a rubber belt (see Fig. 27). A vibrating screen automatically places most of the halves cup side down, before slicing, but it is also necessary for an attendant to properly invert a small percentage of the halves by hand.

Filling the Cans.—From the grading machine the peaches pass by means of belts to the canning tables where the women divert the fruit by means of a small gate located at each canning sink. The empty cans are carried to the canning tables by gravity conveyers from a can loft above the canning room or by overhead conveyer direct from a railroad car, and the filled cans are usually transported from the canning tables to the syruping machines by means of belts.

Inspection.—The fruit is carefully inspected by the women who fill the cans, and blemished or inferior fruit which has escaped the sorters is segregated and sent to the proper table. Forewomen or inspectors inspect the contents of occasional cans from each worker at the canning table in order to maintain uniformity and care in canning and sorting.

Weighing.—The cans are sometimes filled by weight by placing the filled can on a small counterpoised scale. The weight of peaches placed in a No. 2½ can will vary from 19 to 22 oz. The Government regulations require that a No. 2½ can of peaches contain at least 20 oz. of drained fruit. Great care and considerable skill must be employed in filling the cans in order that they may contain the required amount of fruit without crushing. Some factories fill the cans according to the number of pieces per can rather than by weight, although the weight requirement must also be met.

Darkening.—The time which elapses between grading and canning should be as short as possible so that darkening of the fruit through oxidation shall not take place. Oxidation is reduced by keeping the fruit submerged in water at the canning tables and by sprays of water during the grading operations (see also paragraphs on Washing and Blanching).

Can Sizes.—Most of the peaches are placed in Nos. 2½, 2, and 1 tall cans, with the exception of the Pie grade, which usually is canned in No. 10 cans for the use of bakers, hotels, and other similar establishments. A limited quantity of the higher grades is also canned in No. 10 cans for hotel trade. Sliced peaches are frequently canned in No. 1 tall cans and even in 8-oz. cans.

Syruping.—The cans are automatically filled with syrup by syruping machines, described in Chap. VIII (see Fig. 16). The best grade of peaches receives a syrup of 55° Balling and the other grades 40, 25, and 10° Balling and water, respectively, in most California canneries. Some canneries use syrups richer in sugar than those given above, but none use syrups more dilute than these. Peaches low in sugar should be given syrups of higher Balling degree than recommended by the Canners' League standards. Fancy peaches should test at least 30° Balling on the cutout test, Choice at least 22° Balling, Standard at least 17°, and Second at least 11° Balling.

Exhausting.—The filled cans are carried by automatic conveyers from the syruping machines to the exhaust box, in which they are heated in live steam at a temperature of 190 to 212°F. for from 5 to 8 min. The usual temperature is 200 to 203°F. and the time about 4 to 6 min. The first object of exhausting is to expel air from the fruit, the presence of which favors corrosion of the tin plate, and to expand the contents so that on cooling after canning the can will show a good vacuum. The second object is to soften the fruit, so that a larger amount may be placed in the can without crushing.

Exhaust boxes are described in Chap. IX (see also Fig. 18).

FIG. 28.—Canning and sorting peaches. (*Libby, McNeill and Libby, Company; courtesy Canner Publishing Company.*)

It is considered by Bitting (1915) that much better results are obtained by exhausting the fruit at a moderate temperature for a relatively long time than by subjecting it to a short exhaust at a very high temperature. Thus, an exhaust at 180°F. for 10 min. is more satisfactory than a 4 minutes' exhaust at 212°F., for the reason that the high temperature is apt to soften the fruit in the top of the can and will not expel the air from the tissues of the fruit so effectively as exhausting at a lower temperature for a longer time. Exhausting the cans cold under a mechanical vacuum at time of sealing has also been used.

Marking the Cans.—Coding of the cans is extremely important since it is used to designate grade and variety. It may also give the date of

canning and the number of the worker who canned the fruit. Rubber stamps are used to mark the cans or lids with letters or numbers in indelible quick-drying ink to indicate the variety of fruit, its grade and other data of use to the canner. A more common method of marking the cans now is to emboss the code letters on the lid by means of metal dies as the lids pass through the sealer. Many canneries allow the cans to roll through a marking machine after sealing in such a manner that the cans are marked with the number of bands corresponding to the grade. Cans

Fig. 29.—Peach-pitting machine. (*Courtesy Food Machinery Corporation.*)

marked with bands can be quickly found in the stacks in the warehouse and are not apt to become mislabeled.

Sealing.—The centers of the cans usually attain a temperature of 140 to 180°F. in the exhaust box, from which they pass directly to the double-seaming machine. The latter automatically places the caps on the cans and seals them, at the rate of from 25 to 150 cans per minute. The double-seaming machines must at all times be kept in careful adjustment so that the cans may be perfectly sealed and so that loss through leakage and spoilage may be prevented. More spoilage of canned peaches and other fruits through fermentation is caused by faulty double seaming than by any other single cause.

Sterilizing or Processing.—This is the most important stage in the canning process. It should be thorough enough to cook the fruit sufficiently, but not so prolonged that the fruit is badly softened. The length of sterilization will vary greatly with the maturity and variety. The following table gives the length of sterilization for several varieties of the more important canned peaches. Some canners process No. 10 cans of pie-grade peaches at 240°F. for about 30 min.

TABLE 19.—PROCESSING TIMES FOR PEACHES AT 212°F.

Variety and maturity	Size of can, No.	Approximate time at 212°F. in nonagitating cooker, minutes	Approximate time at 212°F. in agitating cooker, minutes
Tuscan Cling, prime ripe	2½	20–25	14½–20
Tuscan Cling, green	2½	25–30	15 –25
Tuscan Cling, prime ripe	10	25–30	
Phillips Cling, prime ripe	2½	35	25 –33
Phillips Cling, green	2½	40	30 –40
Phillips Cling, prime ripe	10	40	35 –40
Muir Freestone, prime ripe	2½	15–20	12
Solid-pack Pie fruit, all varieties	10	40–60	35 –45

Cooling.—Immediately after sterilization the canned fruit should be thoroughly cooled to a temperature where cooking will cease but not low enough to prevent drying of the cans. If the can and contents are cooled to a temperature of 110 to 120°F., drying will take place satisfactorily, and rusting will not occur. If the cans are not cooled sufficiently, the cooking process will continue in the can with the result that the peaches become soft and acquire a dark or pink color.

Testing Cans for Leakage.—As the cans are placed on trays after emerging from the water cooler, they are stored on the cooling floor overnight. They are then tapped with an iron rod to determine whether the sealing has been satisfactory or not.

The percentage of leaky cans will usually be less than ½ per cent. Testing of cans should be done after sterilization so that the faulty operation of the can sealers may be quickly detected in order to permit utilization of the fruit before spoilage occurs. Leaky cans may be opened, recanned as Pie-grade fruit and resterilized.

Storage.—The canned peaches should be stored for several weeks before marketing in order that faulty cans may be detected and so that equalization of the syrup and fruit will take place. The flavor of the product improves during storage.

The cans are placed on the warehouse floor in stacks approximately 15 to 20 ft. high with laths placed between each tier of cans to bind them and to prevent undue strain on the cans at the bottom of the pile.

The warehouse should be cool, dry, and well ventilated and the cans must be protected against the accumulation of moisture . prevent rusting. In cold climates it may be necessary to heat the warehouse in order to prevent freezing of the cans or the condensation of moisture upon them with resultant rusting.

Cutout Tests.—A large number of samples of commercially canned peaches have been examined by the National Canners' Inspection Laboratory in southern California (since abandoned). The following table gives a summary of the results for the year 1919.

TABLE 20.—CUTOUT TESTS OF PEACHES IN NO. 2½ CANS
National Canners' Laboratory, 1919
(*From Miller and Bost*)

New grade*	Old grade*	Average original syrup	Average cutout	Average number pieces	Average net weight, fruit, ounces	Average total net contents, ounces	Number of samples
Second	Second	11.80	11.50	18.62	20.85	29.50	858
Standard	Standard	20.92	14.76	14.68	20.37	29.75	1,140
	Extra Standard	31.30	17.14	12.70	20.20	29.80	1,101
Choice	Extra	40.30	19.77	10.98	19.54	29.95	633
Fancy	Special Extra	53.00	24.75	9.90	17.95	30.50	21

* "New grade" refers to Canners' League grades, and "Old grade" to grades in use in 1919 and since superseded by the Canners' League grades.

The results indicate that the ruling of the Department of Agriculture that No. 2½ cans of peaches contain 20 oz. drained weight of fruit is rather a severe condition to meet in commercial practice. For more recent data on cutout tests for various fruits see Chap. VII. The cutout test varies considerably with the variety of peaches, their maturity, the ratio of fruit to syrup, and the locality and season.

Yields and Waste.—According to Zavalla, a former graduate student at the University of California, there is obtained from a ton of peaches an average of 40 cases of 24 No. 2½ cans each. According to the Dunkley Canning Machinery Company, the average yield is 44 to 46½ cases of cling peaches and 39.8 to 42.75 cases of freestone peaches per ton with use of the spray lye peeler. Their data cover a number of canneries and several seasons' observations. Commercial canners have reported to the writer average yields of from 43 to 48 cases of cling peaches per ton. The average is probably about 45 cases. The pits represent about 12 to 18 per

cent of the weight of the fruit and the loss in peeling 12 to 20 per cent. The total loss in preparation averages about 30 to 35 per cent.

The pits are sent to the dump or are spread in the sun to dry to be used for fuel or sold locally to cannery workers or others for fuel purposes. During the war large quantities of the pits were cracked and the shells were used for the preparation of a carbon of high absorptive power for use in gas masks. The kernels, which comprise about 15 per cent of the weight of the pits, can be recovered and used for the preparation of sweet oil and bitter almond oil, but the cost of recovery is so high that the products cannot economically compete with those from apricot kernels. The whole pits have been dry-distilled to produce acetic acid, acetone, and charcoal, the last being used in poultry foods.

The waste lye solution containing the peels and the waste wash water is of no economic value, and its disposal in some localities has presented a serious problem because the sodium hydroxide renders the soil alkaline and toxic to plants. Further discussion of the utilization of peach and other fruit and vegetable wastes will be found in Chap. XXVII.

Labeling and Packing.—Canned peaches and other canned fruits and vegetables in cylindrical cans are labeled by portable automatic machines. The cans are placed in a runway above the machine by a workman and pass by gravity through the machine. The cans first pass over small rollers which apply the label paste, which may be glue, a casein preparation, dextrin mucilage, or other adhesive. They next roll across a stack of labels, one of which is picked up by the label paste on the can and is smoothed in place automatically by the machine. Adhesive is applied automatically to the end of the label and the label end sealed to the can.

Boxes.—The labeled cans are packed at once into cases, 24 cans of No. 2½ and 48 of small size cans per case, or 6 No. 10 cans per case. Wooden cases were formerly most commonly used, but fiberboard (heavy pasteboard) and corrugated fiberboard boxes are being rapidly adopted by most canners (see Chap. XXIX for discussion of boxes).

APRICOTS

(Prunus armeniaca)

The apricot is second in importance to the peach among California canned fruits. The normal pack of canned apricots is 3,000,000 cases, which represent about 60,000 tons of fresh fruit. This quantity is slightly less than the normal tonnage of fresh apricots dried in California. At an average price of 16 cents a pound for the dried fruit and a yield of 400 lb. of dry fruit per ton of fresh, a ton of fresh apricots will yield a gross revenue of about $64, whereas a ton of the fruit after canning will yield at $2 per dozen No. 2½ cans, approximately $220. Canning is

much more costly than drying. In most cases the overripe fruit is dried, and the prime ripe fruit is sent to the cannery or fresh market.

Varieties.—The Blenheim apricot is the most popular variety for canning purposes. It is of moderate size, of deep yellow color, of excellent flavor, reasonably free from scab or blemishes, and when properly ripened, of uniform texture from the skin to the pit and retains its shape in the can during processing. It is grown most extensively in the counties bordering the San Francisco Bay region in California.

The Royal apricot is grown in southern California and in the hot interior valleys. It is somewhat smaller in size than the Blenheim and of a more intense orange color. However, it is claimed by many nurserymen that the Royal and the Blenheim are identical and that the differences in appearance noted in commercial culture are due entirely to the effect of locality and to climatic conditions. The Royal apricot grown in hot, dry sections often becomes soft near the pit, a condition which renders it more or less unsuitable for canning purposes.

The Moorpark is a very large variety, which is grown in limited amounts in central California. This variety does not bear so heavily or so uniformly as the other two varieties and tends to ripen unevenly. Its large size and excellent quality make it very much in demand for sale in the fresh-fruit markets.

The Tilton is a very important variety grown in the hot, interior valleys of California, in eastern Washington, and in British Columbia. It is of large size but is rather pale yellow in color. It is considered inferior to the Blenheim for canning.

Harvesting.—The fruit on the tree is at its optimum degree of maturity for canning purposes for 1 or 2 days only. If it is too green the canned fruit will have a disagreeable astringent flavor, and no amount of sugar will entirely overcome this defect. If it is overripe, it will be too soft and will be unattractive in appearance after sterilization. When gathered at the "canning ripe" stage of maturity, the fruit is firm, of full size, of good color, and of pleasing flavor. It will not have reached the maximum flavor, however, at this stage of ripeness. There is a tendency now, however, to can apricots soft ripe in the whole condition. This is an excellent product in respect to flavor although rather jam-like in appearance.

The canner desires that the finished product shall retain its clear-cut appearance and that the syrup shall remain clear and reasonably free from pieces of broken fruit. At the same time it is necessary that the fruit have a reasonable amount of flavor. To obtain these results, the apricots should be transported to the cannery as rapidly as possible after gathering and should, if possible, be canned on the same day they are picked, as they cannot successfully be shipped long distances. The trucks used in trans-

porting them should be equipped with good springs to prevent bruising of the fruit in transit.

Apricots are subject to brown rot, *Sclerotinia fructigena*, a fungus which attacks the flowers and green shoots during the spring and the ripe fruit in foggy or rainy weather. It sometimes attacks the fruit in the lug boxes.

Receiving.—Most canners examine each delivery of apricots to determine roughly the percentage of the different grades, and payment is made to the grower on the basis of this "door test." For example, in a typical test 25 lb. of a mixed sample were taken for a grading. Three grades were made, and designated as grades A, B, and C. There was found to be 17 per cent of A, 72 per cent of B, and 11 per cent of C grade, respectively, for which the grower was paid at the rate of $60, $25, and $12, respectively.

Many canners make only two grades, *viz.*, apricots counting 12 or less to the pound and those counting 12 to 14 to the pound, paying much less for the smaller fruit.

Pitting.—The apricots are halved and pitted but are generally not peeled. The fruit is cut by hand around the pit suture and the pits removed. A small proportion of the crop, however, is lye peeled in the same manner as described for peaches, although the lye used is weaker than that used for peaches. The grading of the halved and pitted fruit is carried out in the same manner as described for peaches (for size grades, see Chap. VII). Much of this fruit is now canned unpitted.

Slicing.—A small amount of the largest fruit is sliced and canned for a special trade. It is an excellent article and deserves greater popularity.

Grading.—Screens of $^{40}/_{32}$, $^{48}/_{32}$, $^{56}/_{32}$, $^{64}/_{32}$, and $^{68}/_{32}$ in. are used. The average diameters of the Fancy, Choice, and Standard grades are $^{56}/_{32}$, $^{54}/_{32}$, and $^{50}/_{32}$ in., respectively.

Canning.—The graded fruit is transported to the canning tables on belts in the manner described for peaches, and at the canning tables the fruit undergoes operations, similar to those described for peaches, *viz.*, sorting, washing, and filling into the cans by weight.

Syruping.—The filled cans are syruped in the automatic syruping machines with syrups of the concentrations recommended by the California Canners' League of 55, 40, 25, 10° Balling and plain water, according to whether the grade is Fancy, Choice, Standard, Second, or Pie. Some canners use syrups 5° Balling richer in sugar than those given above.

Owing to its high acidity, the apricot is not pleasing in flavor as a dessert fruit unless it is canned in a heavy syrup, 40 to 55° Balling. There is, however, a good demand for it in lighter syrups and in water for the making of pies.

Exhausting.—Apricots are exhausted as described for peaches.

Sterilizing or Processing.—After exhausting and sealing, the cans are immediately sterilized, usually in agitating continuous cookers. The time of sterilization at 212°F. varies from 4 to 15 min., depending upon the locality and upon the variety and maturity of the fruit. In southern California, Royal apricots were sterilized in agitating cookers for 4 min. at 212° with good results. In central California in the same year, Blenheim apricots were sterilized for 10 to 12 min. in agitating cookers. Too prolonged sterilization will soften the fruit badly. Very little softening of the apricots by cooking is required, and for this reason the cans should be thoroughly and quickly cooled after sterilization.

Canned Pulp.—Some fruit, particularly that which is overripe, is pulped in tomato pulpers, and canned for use in ice cream, etc. In most canneries the Pie-grade fruit is steamed thoroughly to soften it and is packed as solid-pack fruit without the addition of water or syrup. It requires heavy sterilization because of slow heat penetration.

Whole Fruit.—Much fruit is now canned whole. Ripe fruit is graded for size, is sorted, and is canned without peeling; or is lye peeled and canned. The whole fruit requires a longer period of processing than the halved, *viz.*, 20 to 30 min., depending on size of the can.

Yields.—The average yield of canned apricots per ton is about 55 cases of 24 No. 2½ cans. The loss in canning of the unpeeled halved fruit is about 9 to 15 per cent. Where the fruit is peeled, the loss will exceed 30 per cent, based on the weight of the fresh fruit.

Apricot pits are in demand for the manufacture of by-products such as both sweet and bitter "almond oil" and macaroon paste. They are usually dried by spreading in the sun, to a depth of about 1 ft., on a cement floor or on rolled ground, stirred daily until dry, and then placed in sacks to be shipped to by-products plants. Apricot-pit by-products are described in Chap. XXVII.

Table 21.—Cutout Tests for Apricots
National Canners' Association
(*After Miller and Bost*)

New grade	Old grade	Net contents oz.	Net drained weight oz.	Balling degree of syrup	
				Original	Cutout
Second	Second	30.1	18.0	10.9	12.3
	Standard	30.4	17.9	20.5	15.5
Standard	Extra Standard	30.6	17.8	30.6	18.3
Choice	Extra	30.8	17.5	39.7	21.4

Cutout Tests.—The former National Canners' Association Inspection Laboratory in southern California made a careful study of the composition of syrups added to the fruit at the time of canning and the composition of the syrups on the cutout test after canning. The table on page 152 gives a summary of the data.

The tests were made before the adoption of the California Canners' League standards. It will be noted that the net weight of drained fruit is somewhat lower than for peaches, owing to the greater tendency of apricots to soften and shrink during sterilization (see also Chap. VIII).

APPLES

(Pyrus malus)

The apple is canned extensively in the Pacific northwest and the eastern United States, particularly in New York and Pennsylvania. It is used principally for the preparation of pies and sauce in restaurants, hotels, cafeterias, etc. Housewives prefer to use the fresh product or the dehydrated article.

The canning of apples is considered a by-product industry in most apple-growing districts and as a means of utilizing the best quality of culls. The fruit for canning purposes should be of fair size and reasonably free from blemishes. Apples unfit for canning may often be used for cider or vinegar.

Varieties.—Apples for canning should be firm and hold their shape in the can and should be of good flavor, color, and texture. Acid varieties of white flesh are preferred.

On the Pacific coast the Yellow Newtown Pippin and the Spitzenberg are popular for canning purposes. Winesap, or other firm apples of white flesh and of pronounced apple flavor, which can be obtained in commercial quantity, can be used successfully. Mealy varieties, or those that become "apple sauce" during processing or take on a pink or yellow color when cooked, are not so desirable for canning.

Peeling and Coring.—The fruit should be washed and sorted before it goes to the preparation tables. It is peeled by mechanical peelers, operated either by hand or by power; in either case the apples are placed on the peeling knives of the machine by hand. The peeled and cored fruit is trimmed by women who work at another table to which the fruit is delivered by belt or truck; those who do the trimming also cut the fruit in quarters. Ordinarily the fruit is put immediately in dilute brine to prevent oxidation and browning. The peels and cores, which normally represent from 30 to 40 per cent of the weight of the fresh fruit, are usually sent to the vinegar factory to be crushed and pressed for vinegar, although some factories have found it profitable to dehydrate the peels and cores

for the use of jelly and pectin manufacturers from whom there is a good demand.

Blanching.—Before the apples are canned they are usually blanched in one of several ways. A simple process of blanching consists in passing the quartered apples through a steam box to soften them, to destroy the oxidase, and to expel the air from the fruit, thereby reducing pinholing of the tin plate.

In some canneries the fruit is immersed in boiling 3 per cent brine for 3 or 4 min. to accomplish the results mentioned above.

It is possible to remove the air by placing the fruit in dilute brine or water and subjecting it to a high vacuum. The air is effectively removed and water enters the fruit tissues to replace the expelled air, increasing the weight of the fruit considerably. Another method in fairly common use consists in heating the fruit several hours in water at 120°F. or lower temperature which treatment E. F. Kohman finds removes oxygen from the tissues by respiration.

Canning.—Following the blanching operation the hot fruit is packed at once into No. 3 or 10 cans as a solid pack, or a small amount of boiling hot water or dilute brine is added. In most cases, however, the can is practically filled in solid-pack style, and very little liquid is necessary.

Exhausting.—More trouble has been experienced by the corrosion and pinholing of tin plate by apples than by other canned fruit. It has been proved by Bigelow and other investigators that the corrosion is caused by the malic acid of the apples in the presence of air or oxygen and that corrosion is limited or reduced to a negligible degree if the air is thoroughly expelled from the fruit by blanching and from the can and contents by thorough exhausting.

Sterilizing.—Apples are easily sterilized on account of their high acidity, but owing to the fact that the fruit is packed tightly in the cans, heat penetration is not very rapid. Nevertheless a sterilization of 8 to 10 min. at 212°F. in an agitating continuous sterilizer is sufficient.

Pinholing of Tin Plate by Apples.—As noted above a serious problem in the canning of apples is the frequency of corrosion of the tin plate. As proved by Bigelow, Huenick, Wiegand, Todd, and others blanching and thorough exhausting are effective means of preventing corrosion. Huenick, chemist of the American Can Company, recommends the use of a heavy tin plate, *viz.*, Char A-1, and finds that this is more desirable than lacquered tin plate, for the reason that the latter often has small areas that are not perfectly covered with the lacquer. Modern Type-L or similar cold-rolled plate is advised, as it is very resistant to corrosion. This plate has been developed since the work of Huenick.

Corrosion is favored if the cans are allowed to remain hot for several hours after sterilizing. It has been found desirable to invert cans of

ordinary tin plate in the warehouse 3 days after canning and again at 3-week intervals during storage, for the reason that corrosion takes place at the water line in the can and, if the can is inverted frequently, corrosion is distributed over a greater surface (see Chap. XIV. Cans made of Type L plate have eliminated much of this trouble).

BLACKBERRIES

(Rubus villosus)

Large quantities of blackberries are canned in the Pacific northwest for use in the preparation of pies.

Varieties.—In Oregon and Washington, the Evergreen variety, which is an improved strain of the wild blackberry, is most popular.

In California the principal variety is the Mammoth blackberry, which is a hybrid similar in composition and flavor to the loganberry. It is very large, of good color, and of high acidity.

The Lawton blackberry ripens later than the Mammoth blackberry and is smaller and sweeter. It is excellent for jams and preserves and is more in demand for this purpose than for canning. The Himalaya blackberry, a small berry of good color and flavor, ripens in August, September, and October and is canned in small quantities, but owing to the fact that it ripens late in the summer, it is more in demand for the fresh market than for canning. Any good table variety may be used for canning. Very few berries are canned in California.

Harvesting.—Blackberries should be harvested in shallow boxes and should be picked frequently, daily if possible, in order that the fruit may be at the optimum stage of maturity. It is desirable that the fruit be canned on the same day that it is picked, otherwise serious deterioration will take place, even with the greatest care in transportation and storage.

Canning.—At the cannery the fruit is generally merely sorted and very thoroughly washed, very little attempt being made to grade for size. Since most of the fruit is used for pie making rather than for dessert purposes, it is generally packed in water or in light syrups. Fruit for dessert purposes should be packed in syrup of 50 to 55° Balling; lighter syrups do not bring out the rich blackberry flavor, and syrups above 60° Balling cause the fruit to shrivel and become tough.

Because of its very high acidity this fruit must be very thoroughly exhausted, otherwise pinholing and corrosion will be excessive. The length of sterilization required is very short for the reason that the fruit is acid in character and easily sterilized. Eight or ten minutes at 212°F. is sufficient.

In plain tin cans the color of the syrup and of the fruit bleaches rapidly. Therefore it is customary to can the berries in enamel-lined

(lacquered) cans. The preferred can is one made of Type L plate and coated inside with two coats of so called "berry enamel."

The fruit may also be canned as a light preserve after boiling 3 to 4 min. with an equal weight of sugar. In this case no syrup, except that formed in cooking, is added.

LOGANBERRIES

Oregon is a large producer of loganberries, which are used for canning, frozen pack, jams, and juice. The berries are very large in size and deep red in color.

The canned fruit is most in demand for pie-making purposes and therefore is canned in No. 10 enamel-lined cans. The processes of harvesting, canning, and sterilizing are practically the same as for blackberries. "Double-enameled" Type L cans should be used to insure the retention of color. The berries are usually canned in No. 10 cans in water.

RASPBERRIES

(Rubus strigosus)

Raspberries are grown throughout the United States and canned in commercial quantity in the northern and middle Western states, in New York, and on the Pacific coast. The red raspberry is preferred to the black variety for canning purposes but is more in demand for the preparation of preserves and jams than for canning. The berries are canned in lacquered cans, preferably of Type L plate, in heavy syrup for dessert purposes and in water for use in pies. The length of sterilization is usually about 12 min. at 212°F. They may also be canned after cooking a short time with half their weight of sugar.

STRAWBERRIES

(Fragaria Virginiana)

Strawberries for canning purposes should be firm in texture, of good color and flavor, and of large size. The Marshall and Ettersberg are used in the Pacific northwest. The most important requirement is firm texture. The principal difficulty in the canning of strawberries is the softening of the fruit during sterilization, which results in the can containing only from one-third to one-half its volume of berries. Strawberries are used for preserves and for packing in dry sugar in cold storage in very much larger quantities than for canning.

Strawberries shrivel if canned in too heavy a syrup, although a fairly heavy syrup is necessary to develop and retain the berry flavor. A syrup of 50° Balling is satisfactory. Strawberries are much more satisfactory for preserving than for canning.

OTHER VARIETIES OF BERRIES

Currants and gooseberries are canned only in very small quantities, and may be used to better advantage in the preparation of preserves, jams, and jellies.

Blueberries grow wild in abundance in the North Atlantic states, Alaska, and in Scandinavia, where they are gathered and canned for use in pies. According to Bitting, leaves and stems are separated from the berries by a blast of air, and the berries are carefully hand stemmed and sorted. Removal of wormy berries is a serious problem. Severe washing in a cylindrical, rotating wire cage will remove most of such berries, since they are soft and disintegrate under this rough handling. They are usually canned in water, although they are of better flavor if canned in a syrup of 30° Balling.

CHERRIES

(Prunus Cerasus)

The principal districts in which cherries are grown for canning purposes are New York, Michigan, Oregon, and California. In the eastern states the sour varieties are most commonly used, whereas on the Pacific coast a sweet cherry, the Royal Anne, is the principal variety used for canning. This is a large, sweet variety of white or light pink color.

Preparation.—After its arrival at the cannery in most plants, the fruit is first stemmed by hand, although mechanical stemmers have been used in a few canneries. This machine consists of a slightly inclined cylinder about 4 ft. long and about 2 ft. in diameter, which rotates at about 20 to 30 r.p.m. The cylinder is made up of a series of short rubber rollers about 3 ft. long and about 1 in. in diameter. As the cylinder rotates, the rollers are enmeshed at one end by a cogwheel when the rollers are at the lower position during rotation. As the rollers turn, they catch and pull through stems and leaves, leaving the berries uninjured on the inside of the cylinder. The cherries are fed in at the upper end of the cylinder and emerge at the lower end with 95 per cent or more of stems removed. Following the stemming the fruit is thoroughly washed.

It then goes to the same machine used for the grading of peaches and apricots, except that screens with holes of smaller diameter are used. The usual sizes of screen used in the grading of cherries are $^{20}/_{32}$, $^{22}/_{32}$, $^{23}/_{32}$, $^{26}/_{32}$, $^{28}/_{32}$, $^{30}/_{32}$, and $^{32}/_{32}$ in.

These screens yield with good quality fruit the grades established by the Canners' League of California.

TABLE 22.—GRADING SCREENS FOR CHERRIES
(After A. W. Christie)

Variety	Size of screen, inches	Number of cherries per No. 2½ can
Soft Small White	26/32	115
	25/32	120
	24/32	134
	23/32	145
	22/32	158
	20/32	206
	over end	261
Black Tartarian	26/32	105
	25/32	125
	24/32	142
	23/32	156
	22/32	175
	21/32	210
	over end	220
Royal Anne	30/32	70
	29/32	83
	28/32	87
	27/32	94
	26/32	110
	25/32	115
	24/32	135

Pitting.—Most of the sweet cherries are canned without pitting although a large proportion of sour cherries are pitted. The pitting is accomplished by an automatic machine in which cherries fall into small cups and in which the seeds are removed by cross-shaped plungers. The loss in pitting is about 15 per cent of the weight of the stemmed cherry. Considerable juice is expressed from the cherries in pitting and may be recovered for canning as juice or for use in syrups.

Syrups.—The highest grade of cherries receives a syrup of 40° Balling. Syrups of greater density than this cause the fruit to shrivel. The other grades receive in California 30, 20, and 10° syrups and water, respectively.

Exhausting.—Cherries should receive a long exhaust, at least 10 min. at a moderate temperature, at 165 to 185°F., in order to eliminate air and to prevent pinholing. In practice, however, a shorter exhaust at a higher temperature is used, although it is admittedly less desirable. This is particularly true for sour cherries, which corrode tin plate rapidly. Type L or similar plate should be used. G. H. Bohart of the National

Canners, Association recommends a large head space in which the hydrogen formed by corrosion during storage may collect and thus prolong the life of the canned product.

Sterilizing.—The length of sterilization is from 12 to 25 min. at 212°F., depending upon the variety and maturity of the cherries.

GRAPES

(Vitis vinifera)

The principal grape canned in commercial quantities is the Muscat of Alexandria, the highly flavored, sweet European variety of raisin grape grown in California.

The bunches possessing the largest berries are selected for canning purposes. At the cannery the fruit is removed from the stems by hand and defective berries removed and discarded. It is then taken immediately to the graders fitted with $^{20}/_{32}$-, $^{21}/_{32}$-, $^{24}/_{32}$-, and $^{26}/_{32}$-in. openings. The graded fruit is washed, packed into Nos. $2\frac{1}{2}$ or 10 cans, and the cans are filled with syrups of 40, 30, 20, and 10° Balling and water, respectively, for the five grades. After exhausting and sealing, the fruit is sterilized for 12 min. at 212°F.

Thompson seedless grapes are added to fruit cocktail at time of canning. Small quantities also have been canned in water or in light syrup for use in pies as a substitute for gooseberries.

PEARS

(Pyrus communis)

On the Pacific coast the Bartlett pear is the variety almost exclusively used for canning. In the eastern United States the Kieffer is used, because the Bartlett cannot be grown successfully on account of its susceptibility to blight. The Bartlett pear is desirable because of its uniform shape, its white color, and its relatively small number of grit cells. The Kieffer pear is smaller than the Bartlett and of less desirable color and texture.

Harvesting and Ripening.—Pears develop a better flavor and are of finer grained texture if ripened in boxes after picking. Fruit ripened on the tree is apt to be coarse in texture. The pears are gathered at full size, but while they are still hard and green, and are shipped in this condition direct to the cannery where they are held for from 5 to 10 days to ripen. Allen of the University of California and Magness and Diehl of the U. S. Department of Agriculture recommend that pears be picked according to pressure tests made with the Magness pressure tester. The test is made by noting the pressure required to force a $^{5}/_{16}$-in. plunger $^{5}/_{16}$ in. into the flesh of the pear with skin removed. They recommend

that for optimum results the test should be about 17 to 19 lb. and that pears showing a pressure test above 23 lb. should not be used. Color is also a good index of maturity, the color between the lenticels should be a lighter green than the lenticels (for details of the test see Magness, Diehl, and Allen.

After picking, the pears are brought to the cannery in 50-lb. lug boxes for ripening. In most canneries they are stored in a large room, preferably at a temperature of 70 to 75°F. The fruit ripens unevenly, and on that account the boxes of pears must be sorted frequently (daily or every other day) after some of the fruit has ripened. In some canneries the sorting is done directly from the lug box; in others the boxes of fruit are emptied upon a slowly moving belt where sorters remove the ripened fruit, which goes to the peeling department, and return the green fruit to the lug boxes.

Chace and Sorber report experiments in which the ripening of Bartlett pears was successfully hastened by subjecting them to ethylene vapors in the manner commonly used for coloring oranges. The use of ethylene in hastening the coloring and ripening of fruits was discovered by Denny, formerly of Dr. Chace's laboratory of the U. S. Department of Agriculture, and is covered by *U. S. Public Service Patent* 1,475,938, granted in 1923. As applied to pears the lug boxes of fruit were placed in tight rooms or under canvas and exposed intermittently to concentrations of ethylene of 1:1,000 to 1:5,000 in air. Once each 24 hr. the ripening rooms were opened and ventilated for 1 hr., preferably by fan, to remove the products of respiration and to promote uniform ripening. In a typical test the treated pears ripened uniformly and satisfactorily in 4 days, whereas the untreated pears required 7 to 8 days ripening and ripened less uniformly. Where ripening is satisfactory and uniform without ethylene treatment, Chace and Sorber state that its use is of no great benefit. On the other hand, where several sortings are necessary owing to nonuniform ripening, then the use of ethylene is profitable and desirable. Ethylene not only hastens coloring and ripening but also increases the rate of respiration, as evidenced by carbon dioxide evolution.

During ripening the starch of the fruit is converted to sugar, a change that is easily followed by applying dilute iodine solution to the cut surface.

Pears that are too immature when picked do not ripen properly, but become somewhat shriveled, and the flesh after canning is apt to be yellow in color and stringy in texture. Those which are picked too mature are apt to be "grainy" in texture and may become excessively soft around the core before they are fully ripened near the surface.

Quality in canned pears depends to the greatest degree upon picking at optimum maturity, ripening at proper temperature, sorting carefully during ripening, and selecting the fruit for canning at optimum texture (ripeness).

Frequently it becomes necessary to store some of the pears for two or three weeks before ripening and canning. A temperature of about 32 to 33°F. should be used and the lug boxes of fruit should be so stacked that free circulation of air between the boxes is secured. If the boxes are stacked too closely together, the gaseous products of respiration accumulate in the boxes and cause scalding (browning of the skin) and development of off flavors.

Preparation.—The fruit is peeled, halved, and cored by hand, a special guarded knife being used for peeling, the direction of peeling being from the stem toward the calyx, and not around the pear. The core, stem, and calyx are removed by a loop-shaped knife (see Cruess and Christie's "Laboratory Manual of Fruit and Vegetable Products" for appearance of pear peeling and coring knives). At the same time the fruit is graded by hand according to size, usually five grades being made in accordance with the standards of the Canners' League of California, as given in Chap. VII. The Fancy grade represents 8 to 10 pieces, the Choice 10 to 12, and the Standard 12 to 17 pieces per No. 2½ can. In recent years mechanical graders of the diverging cable or roller types have come into use for grading the pears for size before peeling. Fruit to be peeled by the Ewald peeler must first be graded for size.

Pears oxidize and turn brown very rapidly after peeling, and if they are to be held for more than a few minutes, they should be placed in dilute brine, 1 to 2 per cent salt, or in water. Brine checks the action of oxidase, the enzyme responsible for browning.

Pears have been peeled by treatment of the whole fruit in superheated steam followed by removal of the peels by abrasion in a modified potato peeler. At present, however, the trend is toward use of either the Food Machinery Corporation peeler or the Ewald pear peeler. In the former the pear is impaled on a fork-like device by the operator, and it is then carried between safety-razor-like blades that remove the skin to a uniform depth. Other knives cut the pear in half and remove the core and stem. In the Ewald peeler the pear is held in a clamshell-like cup of the size of the pear. Knives of the contour of the fruit, peel the pears to uniform size and shape. With both machines considerable hand trimming is required to remove bits of skin and blemishes. Nevertheless, their use appears to be practicable (see also Chap. VI).

The waste during peeling, coring, and stemming is usually 30 to 35 per cent. The cores and peels can be used in the preparation of vinegar, brandy, or denatured alcohol, although in most factories the waste material is discarded by grinding and washing down the sewer with ample water. If dried, it is useful as stock feed.

Canning and Sorting.—At the canning tables the fruit is again sorted for quality and size. If the surface of the fruit has become browned, the

women at the canning tables remove the brown surface by vigorous rubbing of the pears with the palm of the hand.

Syruping.—The syrups used for the different grades are 40, 30, 20, and 10° Balling and water, respectively. Owing to the pear's low acidity, the 40° syrup is sufficient for the best grade, syrups higher in sugar than 40° Balling imparting too sweet a taste.

Sterilizing.—In an agitating cooker, Bartlett pears in No. 2½ cans require a sterilizing time of approximately 17 min. at 212°F. In non-agitating cookers at 212°F., the processing time is about 25 min.

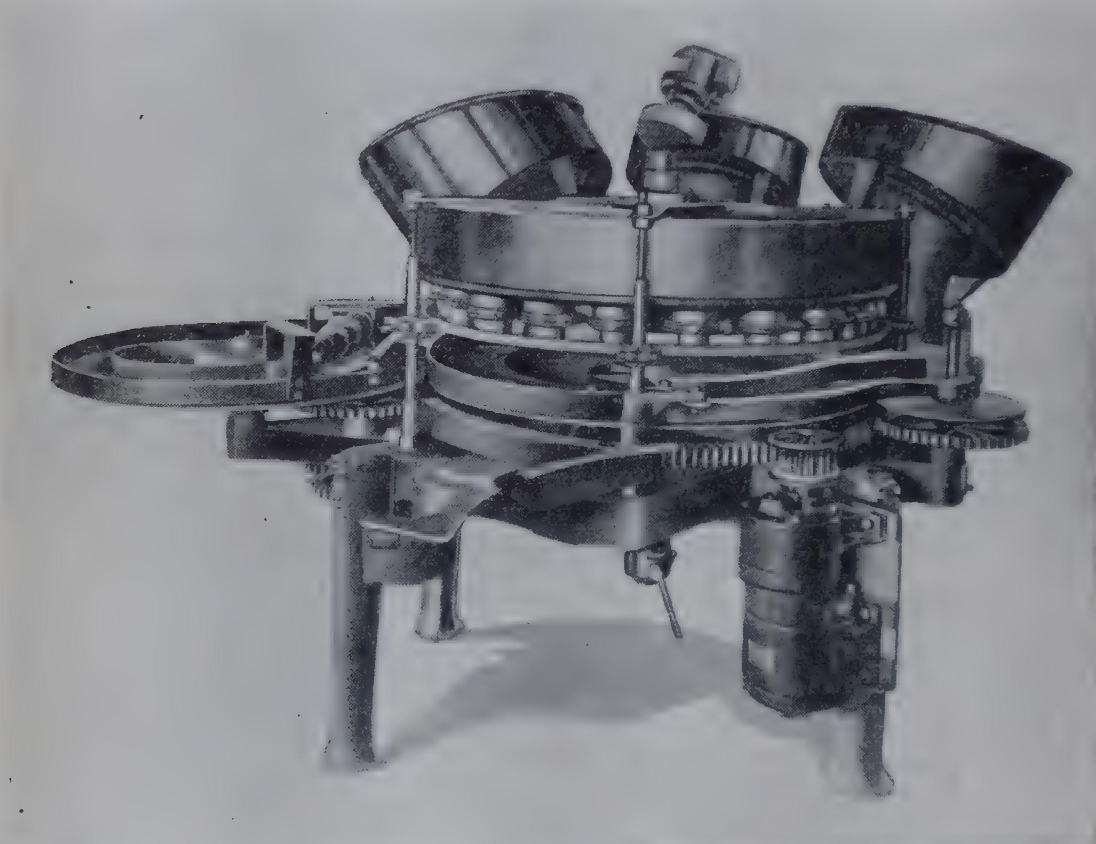

FIG. 30.—Fruit-cocktail can filling machine. (*Courtesy Food Machinery Corporation.*)

Thorough cooling after sterilizing is necessary, otherwise some of the fruit is liable to turn pink in color, as is the case with peaches. "Chalkiness" and yellow color indicate use of immature pears. Dark color of the surface is caused by browning after peeling and before canning.

PLUMS

(Prunus domestica)

The large, sweet varieties of white plums, such as the Green Gage and Yellow Egg, are in greatest demand for canning purposes; the red and black varieties are seldom used.

The plums are sorted and the stems and leaves removed, after which they are graded on vibrating screens containing circular openings of $^{32}/_{32}$, $^{40}/_{32}$, $^{48}/_{32}$, and $^{56}/_{32}$ in. in diameter. Fancy-grade plums are

$^{56}/_{32}$ in., Choice-grade plums $^{50}/_{32}$, and Standard-grade plums $^{42}/_{32}$ in. in diameter.

Plums soften badly in the sterilizing process so that it is difficult to obtain well-filled cans, and on account of their very high acidity there is serious danger of pinholing and corrosion of the tin plate unless the fruit is very thoroughly exhausted. The use of heavily coated tin plate, or of Type L plate, and the application of a thorough exhaust will greatly reduce loss by this type of spoilage. Plums are sterilized from 8 to 14 min. at 212°F.

FRESH PRUNES

In Oregon considerable quantities of the Italian variety of prune are canned in the fresh state. Large, well-ripened, and well-colored prunes are washed, sorted, size graded, and packed in heavily enameled cans, preferably of Type L or similar plate. Syrup of 40° Balling is desirable in order to counterbalance the high acidity of this fruit. Exhausting and processing are about as given for plums.

The Prune d'Agen or "French Prune" of California is less desirable for canning fresh. It should be picked from the tree firm ripe; and should then be lye peeled, as the skin is tough and bursts during processing. A strong lye of about 10 per cent sodium hydroxide is required for peeling. The fruit may be packed in plain tin, Type L plate cans in 30° Balling syrup and exhausted at 200°F. for 4 to 6 min. The canned peeled prunes should be processed in an agitating cooker for about 20 min. at 212°F.

FIGS

(Ficus carica)

Figs are canned extensively in Texas and California and small quantities are canned in some of the other Southern States, particularly Louisiana. In California two varieties are used for canning purposes, *viz.*, the Smyrna or Calimyrna, and the Kadota. The Kadota, a white fig of moderate size, thin skin, firm flesh, and small seed cavity, is an important canning variety. The Calimyrna is a very large variety which during its growth on the tree, requires artificial pollination, or caprification, through the agency of the fig wasp, blastophagus. The Smyrna is not so desirable for preserving purposes as the Kadota for the reason that its seeds are large, the flesh is thin and soft, and the skin inclined to be tough. It is, however, very rich in flavor, high in sugar and fairly satisfactory for canning.

In Texas the Magnolia fig is most commonly used and in Louisiana the Celeste. The Magnolia fig is light brown in color, of moderate size, and of excellent canning and preserving quality. The Celeste fig is

very small and much elongated but, in addition to possessing a very rich flavor, is very firm and retains its form and texture remarkably well in preserving or canning.

Usual California Process.—The Kadota figs are graded for size by a roller grader into four or more grades. In some canneries the figs are "wilted" by a preliminary blanch of 2 to 3 min. in water at about 180°F. They are then blanched in water at about 200 to 212°F. for about 10 to 20 min., the time depending on the size and maturity. They are then canned in No. 1 tall, No. 2½, No. 10, and Eastern Oyster sizes of cans. A syrup testing 55° Balling is added hot to Fancy-grade figs and 45° Balling to Choice grade. The cans are usually exhausted and sealed at once. They are sterilized in boiling water without agitation as follows: No. 10 syrup pack, 2 hr.; No. 10 water pack, 1 hr.; No. 2½ syrup pack, 1 hr. and 50 min.; No. 1 tall, 1 hr. and 40 min.; and Eastern Oyster, 1 hr. and 35 min. An improved procedure consists in packing the "wilted" figs in cans; filling the cans with water; heating in live steam or hot water for about 10 min. to remove the "raw" taste; draining cans; filling with syrup; exhausting; sealing; and processing. The usual designation of the product is "breakfast figs." The Canner's League of California (in San Francisco) has issued grade specifications for figs. Fancy figs must show a cutout of at least 32° Balling and Choice of 27° Balling.

Texas Process.—In Texas the figs are peeled in a dilute, boiling lye solution, and the peels are removed in running water or under streams of water. The fruit is cooked in a heavy syrup to a preserve before canning. Further details of this process will be given under Preparation of Fig Preserves, Chap. XVIII. Figs are also canned in a medium syrup in a manner similar to that described for Kadota figs (see Reed).

ORANGES

Sliced peeled oranges were once canned in California for the use of seagoing vessels and for sale in England, but the demand has been limited. The process used was to heat the sliced peeled oranges in a heavy syrup, approximately 50° Balling, for several minutes at 175 to 185°F. The thoroughly heated fruit and syrup were then placed in cans and pasteurized at not above 185°F. The flavor of the oranges deteriorates after canning and the product is not very palatable after several months' storage. Oranges are canned in Japan quite successfully, the Satsuma type being used.

POMELO, GRAPEFRUIT

(**Citrus grandis**)

Grapefruit is now canned commercially in Florida, Puerto Rico, and Texas for use as a breakfast dish. The fruit is soaked in cold water a

few hours or heated in hot water a short time to soften the rind; this is then removed and the fruit is cored by hand. The segments are then separated and peeled by hand, a very laborious and expensive proceeding. Experiments made in this laboratory in 1915 proved that the segments may be peeled readily by a boiling, 1 per cent lye solution. After removal of the rind, it is customary to lye peel the whole fruit before separating it into segments, a procedure devised by Lefevre of the U. S. Department of Agriculture.

The peeled segments are canned in a dilute syrup or sweetened juice, the cans thoroughly exhausted, sealed, and sterilized at about 180°F. Higher temperatures injure the flavor. Corrosion losses have been rather severe in the past. Thorough exhausting and use of Type L plate appear to be indicated.

Canned grapefruit has proved very popular.

RIPE OLIVES

(Olea Europea)

Since the canning operation represents an incidental step in the preparation of ripe olives, a separate chapter will be devoted to the pickling and canning of this fruit (see Chap. XII).

PINEAPPLES

(Ananas sativa)

Pineapples were canned in Maryland in a small way early in the history of the canning industry, the fruit being shipped to the canneries from Florida, but the Hawaiian Islands and Malay Peninsula now produce most of the canned pineapple of the world.

Pineapples were first grown in the Hawaiian Islands for export in the fresh condition to the mainland, but it was soon found that the market for the fresh fruit was limited and that, in order to insure arrival of the fruit

TABLE 23.—PRODUCTION OF CANNED PINEAPPLE IN THE HAWAIIAN ISLANDS COMPARED WITH CANNED PEACHES IN CALIFORNIA

Year	Pineapple, cases (1 case equivalent to 24 No. 2½ cans)	Peaches, cases
1900	9,800	907,000
1910	625,000	2,145,000
1915	2,700,000	3,239,600
1920	6,752,000	5,731,000
1930	12,672,000	13,771,000
1933	7,815,000	11,150,000

in sound condition, it was necessary to pick it before it had reached maturity. The canning of the field-ripened fruit then followed as a natural sequence.

Growth of the Pineapple Canning Industry.—The increase in the production of canned pineapple during the past 20 years is shown in the table on page 165.

Harvesting.—The fruit is allowed to reach full maturity before it is picked, because if harvested too green and allowed to ripen in boxes it will be lacking in flavor; if allowed to become overripe fermentation will set in, and the fruit will be worthless for canning purposes.

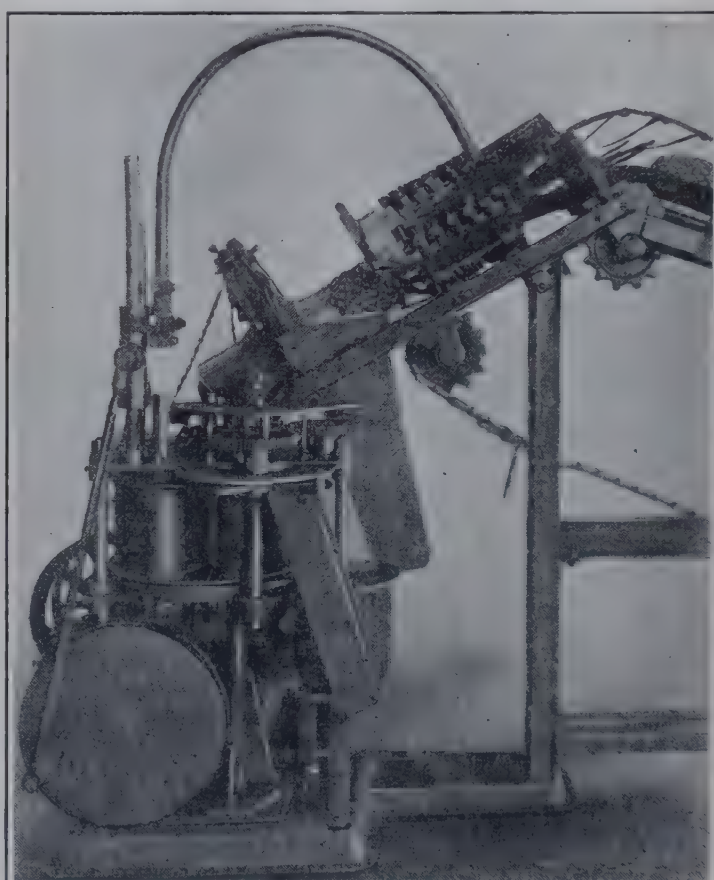

Fig. 31.—A Ginaca machine for peeling and coring pineapples for canning. (*Courtesy Food Machinery Corporation.*)

In picking the fruit, laborers pass between the rows and break the ripe "pines" from the plants by bending them sharply. The fruit is then carried to the nearest roadway where the crowns are cut off and the fruit placed in lug boxes, in which it is taken at once by rail to the canneries.

Most of the fruit is harvested during the months of July and August, although a second crop is gathered in December and January.

Peeling and Coring.—Upon arrival at the plant the fruit is stored out-of-doors on a large receiving platform and is trucked by hand from the platform to the peeling and coring machines, known as "Ginaca machines." This machine is entirely automatic in operation and per-

forms the operations of cutting off both ends of the fruit, sizing, coring and removing the outer shell (see Fig. 31).

Trimming.—A considerable proportion of the fruit contains adhering pieces of shell which must be trimmed before slicing. The cored cylinders of pineapple drop from the Ginaca machine on to a broad rubber belt which carries them before women who carefully inspect each fruit and trim off pieces of shell or blemishes. The pineapple contains an active proteolytic enzyme, making it necessary for the women to wear rubber gloves to protect their hands.

Slicing.—The trimmed fruit is carried by means of a second belt to the slicing machine, but is thoroughly washed en route. The usual thickness is such that eight pieces will fill a No. 2½ or No. 2 can. Each cylinder is cut into circular pieces automatically by the knives of the slicing machine.

Sorting.—The sliced fruit is carefully inspected and sorted by women, as it is carried from the slicing machine on rubber belts. The most perfect pieces are removed first and constitute the highest grade; the second and lower grades are removed as the fruit progresses, and the broken slices are allowed to pass over the end of the belt to be canned as broken slices.

Syruping.—The filled cans are syruped automatically in much the same manner as described elsewhere for peaches and other fruits. This syrup has been made in several of the larger canneries from the waste from the Ginaca machines and trimming belts, which is crushed and pressed. The resulting juice is filtered and neutralized with calcium carbonate at the boiling point and filtered a second time to recover calcium citrate. It may then be decolorized with decolorizing carbon and can then be mixed with cane-sugar syrup and used in canning. This process was developed by Charles Ash and Ralph Gould, chemical engineers of San Francisco, Calif. The pomace may be returned to the fields to furnish humus, or it may be dried and ground for use as stock feed. Subjecting the fruit for a short time to a high vacuum and applying the syrup under vacuum tend to remove air from the tissues and thereby give a clearer product more nearly free of chalky areas. Application of syrup under pressure has also been used for the same objective.

The surplus juice is used in one plant for production of industrial alcohol. Juice expressed from the rinds is not considered very satisfactory for canning for beverage purposes.

Exhausting and Sterilizing.—The filled cans of pineapple are exhausted in steam exhaust boxes at 185 to 204°F. for 4 to 6 min., as described for other fruits.

The cans are then sealed in automatic double seamers and sterilized in agitating continuous cookers at 212°F. for about 10 min. or in agitating

continuous cookers under steam pressure at a temperature above 212°F. and for a shorter time.

Grated or Crushed Pineapple.—There has been developed a machine known as an "eradicator," which is equipped with an adjustable knife set at an angle and with rollers which carry the shells from the Ginaca machine beneath and against the knife. Most of the pulp is cut or scraped from the shells and drops to a broad sorting belt, inside which stand women who remove "eyes" and pieces of shell.

The pulp is then grated or crushed, heated in kettles in syrup, packed into cans, exhausted, and sterilized. It is used extensively for pies, cakes, confections, and salads but is less popular than the sliced fruit for dessert purposes. The product, in spite of the fact that it is in the nature of a by-product, has real merit and its use is extensive in ice-cream factories, bakeries, candy factories, and preserving plants.

Disposal of Cores.—Most of the cores are crushed and pressed for juice, although a limited amount is canned for confectioners' use or is candied.

Grades.—According to Bitting the following grades are recognized:

Extra.—Perfect pieces: free from eyes or portions of eyes, free from peel; fruit of perfect color (light yellow), of tender texture, but firm enough to hold up in processing.

Extra Standard.—Perfect slices with all characteristics of extra grade but may be lighter in color, or a little greener.

First Standard.—Sound fruit with some imperfections in color or in cutting and may exhibit some variation in ripeness or color.

Second Standard.—Contains more light fruit and imperfect pieces than the First Standard grade.

Fifth Grade.—Broken pieces and irregular or spotted slices.

The fourth and fifth grades are sometimes shredded or crushed. According to one writer, the syrups used for the three highest grades are 55, 50, and 40° Balling, respectively. Another authority gives the syrup for the Extra Grade as 51° Brix and the cutout as above 25° Brix.

FRUITS FOR SALAD

The packing of mixed fruits for use in salad and dessert has become a very important part of the fruit-canning industry of California. The author first encountered this product about 15 years ago, at which time the J. C. Ainsley Packing Company of Campbell, Calif., was canning mixed fruits in a syrup containing sufficient gelatin to form a jelly on cooling. Subsequently the gelatin was omitted and the fruits were canned in plain syrup of medium density. At present practically all fruit canners pack this item. It was formerly labeled "Fruit Salad" but the federal food administration ruled that it is not a salad but rather

a mixture of fruits that may be used in preparing salad; hence the present designation "Fruits for Salad."

In the early years of the industry apricots, peaches, and pears were canned in season in No. 10 cans, later the cans were opened, these fruits were mixed with canned pineapple and Maraschino cherries, and the mixture was recanned. About 1932 the Schuckl Canning Company found that fresh peaches and pears could be used successfully for the purpose, and now it is universal practice to can the fruits for salad during the peach and pear season in August and September.

Bartlett pears and clingstone peaches are prepared as for canning, by halving and peeling or coring. The peaches are given a preliminary steaming to soften them sufficiently that they will be of proper texture when processed with the other fruits in the canned fruits for salad. Most of the halves of pears and peaches are cut in half lengthwise; some for small cans may be cut in thirds. Canned, sliced pineapple is placed on an upright metal rod and forced down by a single operation through fixed blades that cut each slice into eight segments. Number 10 cans of apricots also are opened; these having been canned firm ripe in season, usually in a Choice grade syrup, and given a light processing, sufficient to prevent spoiling but not sufficient to unduly soften them. Maraschino cherries, dyed with erythrosin dye, as described in Chap. XVIII, are prepared in bulk during the fruits for salad canning season or are purchased in bulk from local preservers.

The syrup from the canned pineapple and apricots is recovered, mixed with a filter aid—such as Hy-Flo infusorial earth—filtered hot, and then mixed with sufficient water and sugar or cane-sugar syrup to give the syrup required for canning the fruits for salad.

In canning "the Ford automobile assembly line" system is followed. Girls stand or sit at stainless-steel, or porcelain-lined steel-sinks filled with the respective fruits. Cans pass slowly before them on a rubber belt or other conveyer. One girl adds to the bottom of the can the specified number of Maraschino cherries, the next adds apricots, the next adds pineapple, the next adds peaches, and the last adds the pears. As the cherries always "bleed" slightly, *i.e.*, give up some erythrosin dye to the adjacent fruit, and as apricots show the dye less than do pears, the former are placed adjacent to the cherries and the latter as far as possible from them.

Syrup is then added by syruping machine, the cans are exhausted, sealed, and processed in an agitating continuous cooker. For No. 1 tall cans the process is about 10 min. at 210 to 212°F. and slightly longer for the No. 2½ can. Exhausting should be thorough.

The Canners League of California has established the following specifications for Fancy and Choice grades of canned fruits for salad.

Fancy Fruit for Salad.—Fruit to be of good color, ripe yet not mushy, of uniform size, symmetrical, and free of blemishes serious for Fancy grade fruits. Apricots, Bartlett pears, and yellow cling peaches must be at least equal in quality to canned Choice fruits, and the pineapple at least equal to Fancy tidbits. The Maraschino cherries must not be smaller than seven to the ounce. The apricots must be in halves; pears and peaches in halves, quarters, sixths, or eighths; pineapple in sectors; and the cherries whole. The apricots constitute 18 to 30 per cent, pears 21 to 33 per cent, peaches 24 to 40 per cent, pineapple 9 to 16 per cent, and cherries 4 to 8 per cent of the total drained weight.

The average drained weights of fruit in various sizes of cans must be:

Ounces	Can No.
5	3-in. 8-oz. can
5½	3¼-in. 8-oz. can
10½	No. 1 tall can
13	No. 2 can
19	No. 2½ can
68	No. 10 can with a tolerance of 5 per cent, provided the can does not appear to be slack filled. Counts of each fruit per can are also specified.

The syrup after canning and reaching equilibrium with the fruit must be at least 24° Brix (or Balling); with a permissible tolerance for any single package of 10 per cent, *i.e.*, it may be as low as 21.6° Brix.

Choice Grade Fruits for Salad.—The specifications are similar to those for the Fancy except that the California fruit must be at least equal to the regular Standard canned fruit in quality and the pineapple equal to or better than Standard tidbits. The syrup after canning must test 20° Brix or above with a tolerance of 10 per cent, *i.e.*, not below 18° Brix for any package.

FRUIT COCKTAIL OR FRUIT STARTER

In 1920 to 1925 the Fruit Products Laboratory of the University of California packed for local distribution and sale a mixture of diced fruits in medium syrup under the label of Fruit Cocktail. Sales and interest were excellent, indicating that the product might meet with popular favor. Several years later the product was packed by a small cannery, that of H. E. Gray, near San Jose, Calif. It was immediately successful and has since become a regular item in all large California fruit canneries.

During the Bartlett pear-yellow clingstone peach season these fruits are peeled, halved, pitted or cored, and diced by machinery to give pieces that will pass through a ¾-in. opening. Maraschino cherries are cut approximately in half by machine. Canned pineapple slices are cut in segments. Thompson seedless (Sultanina) grapes are stemmed by

machine or by hand, sorted, washed and graded for size. The cut fruits are sorted to remove unfit pieces.

Approximately twice as much peach as pear is added per can. The mixing and filling of the cans are done largely by an ingeniously devised automatic machine. Syrup of density suitable for the grade is added, the cans are exhausted and processed at 210 to 212°F. in an agitating continuous cooker. The process is sufficient to cook the yellow cling peaches until tender without unduly overcooking the pears.

Fancy Fruit Cocktail.—The Canners League specifications for this grade are as follows: Peach and pear pieces must be characteristically cubical to right-triangular pyramidal in shape, of such size that they will pass through a square ¾-in. opening; and they must not exceed ¾ in. in length. The grapes must be of at least Choice quality. Peaches must constitute not less than 30 per cent or more than 50 per cent of the total drained weight; pears not less than 25 per cent or more than 45 per cent; grapes not less than 7 per cent or more than 14 per cent; and cherries not less than 2½ per cent or more than 6 per cent.

The average drained weights of fruit for various sizes of cans are:

Ounces	Can No.
5¼	3-in. 8-oz. can
5¾	3¼-in. 8-oz. can
11	No. 1 tall can
13½	No. 2 tall can
20	No. 2½ can
72	No. 10 can

A tolerance of 5 per cent is permitted.

The syrup after canning must test at least 24° Brix; a 10 per cent tolerance being permitted for any single can.

A tolerance of 15 per cent by weight of pieces of peaches that do not conform to the specified sizes and 10 per cent for pears is permitted.

Choice Fruit Cocktail.—The Canners League specifications are similar to those for the Fancy grade, although the pieces may be somewhat smaller. The syrup after canning must test at least 20° Brix (with a 10 per cent tolerance). A tolerance of 20 per cent by weight is permitted for the various fruits that do not conform to the size and shape specified

CANNED CRUSHED FRUITS OR SAUCES

The canning of crushed pineapple has been discussed in the section on pineapple canning. Crushed fruit preserves are used extensively by the ice-cream industry and are discussed in Chap. XVIII. Experiments conducted by the staff of the Fruit Products Laboratory in cooperation with commercial canners have demonstrated that there is considerable

consumer interest in canned crushed fruits in a medium syrup for use as a breakfast sauce, or in various desserts such as pies, whips, gelatin desserts, puddings, etc. Sauce is perhaps a better term.

Peaches, pears, or apricots are prepared as for canning. They are then ground coarsely in a large-sized food grinder equipped with a plate with ½-in. openings. Cans are filled about three-fourths full with the ground fruit, and syrup of 40° Brix is added to fill the can; or preferably the syrup may be added to the cans first and fruit then added to fill.

The cans must be given a long exhaust in live steam, 10 to 12 min. at 200 to 212°F., since heat penetration is very slow.

They are then sealed and given a process at 210 to 212°F. of about 10 to 15 min. for apricots, 15 to 20 min. for cling peaches, and about 20 min. for pears, in an agitating cooker. An alternative method consists in adding 1 lb. of sugar to 6 or 7 lb. of the ground fruit, heating to boiling, canning hot, sealing, and processing at 212°F.

Figs may be canned in similar fashion but because of their low acidity require a process of 1½ hr. at 210 to 212°F. in a nonagitating cooker.

These fruits are much less sweet than fruit jams or preserves and can be eaten in generous servings. They are satisfactory not only for household use but also for commercial use in ice cream, ices, bakery products, and as candy bases.

SIEVED FRUITS

Fruits in the form of purée are canned in small cans as foods for infants. There may be a potential demand for such products for general household use and for use in soda fountains, bakeries, and ice-cream factories.

Fresh fruits are prepared as for canning and are then steamed until soft, when they are then passed through the fine screen of a tomato-juice extractor or through a tomato cyclone as in making tomato purée. In order to give a smooth consistency the purée should be passed through a tomato catsup finisher.

It may be canned sweetened with about 1 lb. of sugar to 6 or 7 lb. of purée or may be canned without added sugar. Most fruit purées are very thick; consequently heat penetration is slow. It might be advisable to heat them nearly to boiling in an open kettle or in a continuous stream in a steam-jacketed pipe. The contents of small cans should be about 180°F. when sealed and No. 10 cans about 160°F.

If sealed at these temperatures, the processing period need be only about that for the corresponding canned whole or halved fruits.

The lightly sweetened purées are excellent for household use in frozen desserts, in homemade milk shakes, etc.

APPLESAUCE

Canned applesauce has met with favorable response. The preferred method of preparation consists in peeling, coring, and slicing or quartering the fruit by machine. The prepared fruit must be carefully sorted.

It is cooked with the required amount of sugar, *viz.*, 20 to 25 per cent by weight, until it is nearly a sauce. It is then canned scalding hot, sealed, given a short process of about 5 to 10 min. in 8 oz. to No. $2\frac{1}{2}$ cans, and thoroughly cooled. Type L cans should be used, as corrosion is severe on ordinary tin plate.

Copper must be avoided as it discolors the product. Overcooking must be avoided, or the sauce may be dark in color and too soft. This product is known as "lumpy" applesauce and is much like that made in the home from fresh apples.

A cheaper and less desirable product is made by treating the whole apples to remove arsenical spray residue; steaming until soft; passing the fruit through a tomato pulper; kettle cooking with the required amount of sugar; canning hot; sealing and giving a short process at 212°F. This product is smooth in consistency, darker in color, and poorer in flavor than the "lumpy" sauce. It may be satisfactory for use in lumber camps, etc., but it is less satisfactory for household use than the lumpy sauce.

CANNED FRUITS FOR PIE

The canning of pie-grade fruits in No. 10 cans for bakers' use has been described elsewhere (see individual fruits). At present there is on the market no water-packed or solid-packed canned fruit for household use in making pies, jams, sauces, and other cooked products. It is the writer's belief that a potential market exists among housewives for such a product, in view of the fact that in 1920 to 1924 such a product was packed experimentally and successfully sold in Berkeley, Calif., by the Fruit Products Laboratory.

Peaches and pears were peeled, halved, and cored or pitted as for canning. They were then sliced in a rotary slicer in pieces about $\frac{1}{8}$ to $\frac{3}{16}$ in. thick. The slices were filled "jumble-pack" style into No. $2\frac{1}{2}$ cans in order to give spaces between the slices; water was added to fill; the cans were heavily exhausted and processed at 212°F. 20 to 25 min.

Apricots were canned halved but unpeeled and unsliced, in No. $2\frac{1}{2}$ cans, water being used instead of syrup to fill the cans. Plums could be canned whole in water. Colored fruits such as loganberries, blueberries, blackberries, currants, pie varieties of sour cherries, and red or blue plums would require heavily enameled Type L or similar tin plate in order to retain color and prevent excessive losses from corrosion.

CRANBERRIES

The canning of cranberries has become an important industry in New England. Apparently the most popular product is a jellied cranberry sauce. The sorted, washed berries with about an equal weight of sugar may be cooked in kettles to the jellying point, filled into enamel-lined, Type L cans or cans of similar character, and sealed scalding hot, no further processing being required; or they may be cooked as above and passed through a tomato pulper before canning in order to give a smooth sauce. Monel metal or other resistant alloy or metal should be used because of the high acidity and intense red color of the fruit. The canned sauce has largely displaced homemade cranberry sauce for use during the holiday season.

CANNED DRIED FRUITS

During the hot summer months dried fruits in boxes or cartons do not keep well because of excessive "drying out," "sugaring," molding, and attack by insects. The same is true in the tropics at all seasons. Consequently there is a place in the marketing scheme for dried fruits packed in tin or glass in order that the undesirable changes mentioned may be prevented and thus the distribution of dried fruits extended to the summer months and the tropics.

Ready to Serve Dried Prunes.—The procedure as developed by E. Mrak of this laboratory is as follows; Large size, unprocessed, previously size-graded dried prunes of the Prune d'Agen (French prune) variety are carefully sorted, thoroughly washed, and heated in boiling water for 3 min. They are rinsed and then packed in Type L cans or cans of similar plate. The "going-in" weights of the processed prunes are 3 lb. per No. 10 can and 14 oz. per No. 2½ can, weights for other cans being in proportion.

Syrup of about 20° Balling is added to fill the can; the cans are exhausted 16 min. at 200°F. or above; sealed, and processed 45 min. at 212°F. A generous head space, about ⅜ in., should be left to provide space for accumulation of hydrogen gas, as prunes attack tin plate actively. Type L cans should be used.

Corrosion is much less severe and the "shelf life" of the canned product is greatly prolonged if the syrup used in canning is acidified with 0.40 gram of citric acid per 100 cc. or with an equivalent amount of concentrated lemon juice.

If the syrup is of too high a sugar content, the canned prunes will be shriveled in appearance and tough in texture.

The Canners League specifications call for the following drained weights at 30 days, or longer, after canning:

	Ounces
3-in. 8-oz. can	6¼
3¼-in. 8-oz. can	6¾
Picnic size can	8
No. 1 tall can	12
No. 2 tall can	15
No. 2½ can	22
No. 10 can	79

The syrup must be not less than 20° Brix at time of canning.

According to Mrak, if a syrup of 20° Brix is added, it will after canning increase to about 40° Brix, as the fruit is much higher than the syrup in sugar content.

So-called "Dry-pack" Prunes.—Mrak recommends the following procedure for this product. French variety dry prunes of 50 to 60 size are processed in boiling water for 4 min., are drained, and are packed scalding hot in enamel-lined cans. The lids are placed on cans and given the first rolling operation; the cans are exhausted 20 min. in live steam and sealed. They are allowed to cool in the air. These prunes are for cooking later with water and serving in the usual manner.

Another syrupless product developed by Mrak and the author is canned at rather a high moisture content in order that the fruit may be eaten out of hand satisfactorily without further treatment. The dried prunes are graded for size and are then cooked in boiling water until the flesh has attained about 32 to 33 per cent moisture. After a few trials a cooking time can be established that will give this moisture content. The scalding hot prunes are packed into double-enameled, Type L plate cans; but they should be packed rather loosely in order to minimize pin-holing and hydrogen swelling. The cans are exhausted at 200 to 205°F. for 5 or 6 min., sealed and processed at 212°F. for about 30 min. for small cans such as 8 oz. and No. 1 tall. Numbers 2 and 2½ cans should be processed 40 to 45 min. Cool thoroughly. Key top cans may be used if desired. These prunes are greatly relished by children as a between meal food. They have the advantage also that 5 to 10 min. boiling in water, or water with a small amount of added sugar, cooks them sufficiently for serving as breakfast prunes.

Canning of Raisins.—At one time the Kings County Packing Company of Armona, Calif., canned seeded Muscat raisins for distribution in the tropics or during the summer months when carton-packed dried fruits do not keep well on grocers' shelves owing to molding, sugaring, and insect infestation. Canning prevents such losses and preserves the raisins at their moisture content at time of canning.

Considerable spoilage was encountered from fermentation and separation of dextrose crystals after canning. Parcell in this laboratory established that fermentation was due to yeast that survived the very

mild pasteurization used by the cannery and that separation of dextrose crystals was caused by too low a moisture content.

An improved procedure based on his experiments was about as follows: The raisins as received from the grower were stemmed by machinery and were dried to a low moisture content, about 8 per cent, at 145°F. Higher drying temperatures volatilized the Muscat aroma and caramelized the flesh. They were then "cap stemmed" (treated by machine to remove the small stems on each raisin). Next they were heated in hot water and seeded by machine. The seeded raisins were packed into 8- and 12-oz. cans and sufficient water added as determined by experiment to give 33 per cent moisture.

The cans were exhausted at 180 to 185°F. for about 10 to 12 minutes, sealed hot, and processed at 180°F. until heated to the centers, usually about 30 to 35 min.

While temperatures of 200 to 212°F. may be used for exhausting and processing, the flavor is injured less at 180 to 185°F.

Seedless raisins also were canned successfully by a similar procedure.

It is advisable to use Type L plate cans since the raisins react rather severely upon common coke plate and will in time cause hydrogen swelling. For the same reason considerable head space should be left and cans sealed at not less than 175°F.

Figs.—Unsulfured dried figs may be canned very successfully by the procedure outlined for dry-pack prunes.

Sulfured Fruits.—Sulfured dried fruits act very severely upon plain tin plate, causing detinning, blackening, and hydrogen swelling. In heavily enameled cans they may be packed fairly satisfactorily under high vacuum. They should be of fairly high moisture content, about 22 to 24 per cent.

The major difficulty is that after a few months' storage the sulfur dioxide content of the fruit drops to a level at which darkening occurs, thereby shortening the shelf life of the product materially.

BAKED CANNED FRUITS

At various times in the past canners have attempted to can baked pears and apples. Nichols of this laboratory developed a satisfactory procedure for baking and canning pears. The firm ripe pears were cut in half and placed on upright steel skewers on a metal conveyer and were carried through a bread-baking oven to bake them to a brown color. They were canned in a heavy spiced syrup. A more pleasing product is made by sprinkling the cut surface of the fresh pears with sugar and baking in shallow pans as is done in the home; then canning in a spiced syrup.

Apples are peeled, cored, halved, sprinkled with sugar, baked, and canned in a spiced syrup.

Peaches may be prepared and canned in similar fashion satisfactorily.

Note on Canned Specialties.—The trend at present is strongly in the direction of canned specialties and novelties such as canned juices, fruit cocktail, fruits for salad, sieved fruits, crushed fruits, etc. Canners, therefore, must keep abreast of such developments and be prepared to take advantage of them.

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CHAPTER XII

PICKLING AND CANNING OF RIPE OLIVES

According to certain ancient writers olives were pickled in a crude way in salt or were treated with wood ashes to remove the bitterness and to preserve them. Methods of pickling now in use are of comparatively recent development. The present chapter deals only with the canning of ripe olives. See Chap. XXV for Spanish style green olives, Greek style olives, etc.

Extent of Industry.—The California canned ripe olive has appeared on the market only during the past 30 years, but in that relatively short period ripe-olive canning has become an important industry. The usual annual production in California is about 700,000 cases, or approximately 3,500,000 gal. of canned, ripe, pickled olives. The United States imports normally about 6,000,000 gal. of green olives (equivalent to about 1,200,000 cases).

About 1900, F. T. Bioletti of the University of California discovered that ripe olives, after a preliminary pickling process to remove the bitterness, could be canned and preserved by heat in the same manner as other food products. The olive-pickling factories of the state were quick to realize the advantage of this method of preservation and to adopt it. He used 212°F. for processing. Later developments, *viz.*, outbreaks of botulism, proved that this temperature is inadequate and unsafe. Present processing is at 240°F. for 60 min.

Varieties.—The most important variety is the Mission, and over 80 per cent of the acreage is of this variety. The fruit is of medium size and oblong in shape with a pronounced point at the blossom end. It is rich in oil, of firm flesh, and of excellent pickling quality. It is not so large as the other varieties but is superior to them in flavor, texture, and oil content.

The Manzanillo olive is the second in importance. It is cherry-shaped, slightly larger, and ripens about 2 weeks earlier than the Mission. For this reason it is preferred to the latter in districts subject to early frosts. It is used in Seville, Spain, for green pickling and is very popular as a stuffed green olive.

The Sevillano or "Queen olive" is third in importance and is the variety grown in Spain for the preparation of the large Queen green olive. Most of the fruit is an inch or more in diameter, as compared to $\frac{3}{4}$ in.

or less for the Mission. The Sevillano is more tender in texture and very much more difficult to pickle than either the Mission or the Manzanillo. On account of its very large size, however, it is in demand and in certain districts of California the orchardists are grafting the Mission and Manzanillo trees with Sevillano scions. The Sevillano derives its name from Seville, Spain, where it is the most important variety used for green pickling. In Spain it is known as the Gordal.

The Ascolano variety is nearly as large as the Sevillano. After pickling it is crisp in texture and of pleasing flavor. It is a favorite in Italy, and derives its name from the town of Ascoli. In Italy it is known as "oliva bianca d'Ascoli."

Chemical Composition of Olives.—Unpickled olives are intensely bitter. A number of chemists, principally Bourquelot, Vintellesco, Power, and Tutin, have investigated the chemical nature of the bitter principle. Power and Tutin believed that the bitterness is due to gums or tannin, while Bourquelot and Vintellesco contend that the bitter principle is a glucoside, to which they have given the name "oleuropein." The present writer obtained it in purified form in 1930 and studied its properties. It is a levorotatory glucoside, yielding α-d-glucose on acid hydrolysis. It reduces Fehling solution and on alkaline hydrolysis yields caffeic acid and a levorotatory complex, free of bitter taste.

The bitterness is destroyed by dilute alkali at room temperature, and neutralization of the excess alkali does not cause a return of the bitterness after it has been destroyed by the alkali. The bitterness can also be destroyed by treatment with dilute acid in an autoclave under pressure. The principal step in the pickling process consists in the destruction of the bitter principle with sodium hydroxide.

The flesh of ripe olives of the Mission variety contains from 20 to 25 per cent oil, that of Manzanillo olives about 16 to 18 per cent, and that of the Sevillano and Ascolano varieties less than 15 per cent.

In addition to oil, the fruit contains normally from 6 to 10 per cent of soluble solids, of which mannite is one of the most important constituents. The juice of the Mission olive is acid in reaction and, when titrated with one-tenth normal alkali, is equal in acidity to a 0.4 to 0.5 per cent citric acid solution. It is probable, however, that the acids in the olive are complex in nature and are not so simple as citric, malic, or tartaric acid.

In the pickling process most of the soluble compounds are removed by leaching. Olive oil remains in the pickled product as the principal constituent of the flesh, the remainder being mainly crude fiber. The following table published by M. E. Jaffa of the Nutrition Division of the University of California will indicate the comparative fat content of the olive and of several staple food products.

TABLE 24.—COMPOSITION OF RIPE PICKLED OLIVES AND SEVERAL OTHER FOODS
(*After M. E. Jaffa*)

Food	Water, per cent	Protein, per cent	Fat, per cent	Carbo-hydrates, per cent	Ash, per cent	Fuel per pound, calories
Olive, ripe	69.60	2.00	21.00	4.00	3.40	958
Olive, green	78.41	2.43	12.90	1.78	4.48	598
Cucumbers, pickles	93.80	1.10	0.40	4.00	0.70	110
Bread	35.30	9.20	1.30	53.10	1.10	1,215
Rice, boiled	72.50	2.80	0.10	24.40	0.20	525
Potato, boiled	75.50	2.50	0.10	20.90	1.00	440

Picking.—For ripe pickling, Mission and Manzanillo olives are at the optimum stage of maturity when the color of the fruit has become cherry red. Fruit that has arrived at the jet-black stage is apt to soften in the pickling process and that which is green in color yields a tough pickled product of poor flavor. Sevillano and Ascolano olives are picked at a less mature stage since they soften severely during pickling if the fruit shows much color when picked.

R. W. Hilts, Director of the Pure Food and Drug Laboratory of the U. S. Department of Agriculture in San Francisco, has made a tentative recommendation that the flesh of the Mission olive shall contain at least 17 per cent oil and of the Manzanillo at least 15 per cent oil if the pickled product is labeled "ripe." He has made no recommendation for the Sevillano and Ascolano varieties. If the fruit has reached the cherry-red stage of maturity it will, in most cases, conform to the minimum standards suggested by Hilts. A similar study made recently by Pitman indicates that the recommendations made by Hilts are very reasonable.

The unpickled olives are extremely sensitive to bruising and great care, therefore, must be exercised in picking the fruit and transporting it to the factory. Buckets made of canvas are commonly used in picking and the buckets of fruit are emptied into shallow lug boxes fitted with cleats to protect the olives against bruising, when the boxes are stacked.

In the early districts in California the picking season begins about Oct. 1 and in favorable seasons may last until the first of December.

Holding Solutions.—Most factories do not possess a sufficient number of vats to care for all the fruit as rapidly as it arrives. It is therefore necessary to store a considerable proportion of the crop in dilute brine until the pickling vats become available. It is customary also to ship olives in dilute brine, when they are in transit more than one day. The concentration of the brine ordinarily used for shipping purposes is from 3 to 5 per cent salt, and of that used in the factories for storage purposes from 5 to 10 per cent salt. A 7 to 10 per cent solution should be used for

storage of more than 2 weeks. A hydrometer known as a salometer is employed in testing the strength of the brine. A 3 per cent solution is equal to about 12° salometer and 10 per cent equal to about 40° salometer (see Table 76).

The holding solution improves the texture of the fruit and makes pickling possible in a shorter length of time than when pickled directly after arrival at the plant.

Fermentation in Holding Solution.—The writer has investigated the changes that take place during the storage of olives in dilute brine and has found that, in solutions containing less than 6 per cent salt, there is rapid formation of lactic acid, the concentration of the lactic acid normally increasing to about $\frac{4}{10}$ of 1 per cent. It is probable that the lactic acid acts as an antiseptic and checks the growth of putrefactive organisms. It was found that olives stored in water or $1\frac{1}{2}$ per cent brine often become slimy and soft through the growth of mold and putrefactive bacteria. When stored in a brine 8 per cent salt (32° salometer) the olives fermented normally and remained firm. This concentration is recommended after the first 10 to 15 days' storage of Mission and Manzanillo olives in order to check growth of gas and slime-forming organisms. Owing to danger from shriveling in strong brines, it is customary to store Sevillano and Ascolano olives in brine of 20 to 28° salometer. If the lower concentration (20° salometer) is used the brine should be acidified to about 0.5 per cent acidity with edible lactic acid in order to prevent spoilage.

Deterioration in Holding Solution.—If the olives are placed directly in a 10 per cent salt solution, they are apt to shrivel badly. It is therefore necessary to increase the concentration of the brine progressively by small additions of salt from day to day. This is particularly true of Sevillano and Ascolano olives.

If bacterial growth is very pronounced, the olives become bleached in color. This apparently is caused by a reducing action because the color can be returned to the fruit by oxidation. If the salt concentration is too low or the acidity insufficient, bacterial softening is very apt to occur, owing to action of bacteria of the *Bacillus coli* group. At the first sign of such spoilage the brine should be acidified with 0.5 per cent lactic or 0.25 per cent acetic acid. Gas blisters often form in such spoilage and are responsible for the term "fisheye spoilage."

Storage for 6 weeks or longer in holding solution appears to be desirable if its optimum effect is to be obtained. The length of time that olives may be held in satisfactory condition in a holding solution varies according to the variety of the fruit, the storage temperature, and the concentration of the brine. Olives of the Mission variety have been held for 10 mon. in a strong brine solution without appreciable deterioration in quality.

Grading before Pickling.—In most factories the olives are graded for size before they are placed in the pickling vats, usually with a grader that consists of moving diverging steel cables similar in design and operation to orange graders. Cherry graders have been employed, but because of the oblong shape of most olives, the screens with circular openings do not give satisfactory separation of the olives. The roller grader used for oranges has been successfully modified in size and design to make it suitable for the grading of olives. The most popular grader at present is the Sammis diverging-cable grader. It is accurate and has a large capacity.

The unit for designation of the different size grades is $\frac{1}{16}$ in., the largest being $\frac{17}{16}$ in. in diameter and the smallest size normally used for pickling $\frac{10}{16}$ in. in diameter. Olives smaller than this are used for oil, olive mince, etc.

It is desirable to grade the olives for size before pickling in order that the action of the lye may be uniform. It requires a much shorter time for the lye to penetrate the flesh of small than of large olives, and for this reason if the small and large fruit are pickled in the same vat, the small fruit will be softened and bleached by excessive lye action, or the large fruit will remain bitter. In addition to grading the fruit for size, it is customary in some factories to sort it carefully for color into three grades, respectively, black, cherry-red, and green fruit. Overripe fruit is more subject to injury by lye action than the green fruit. On this account the sorting of the fruit into grades representing the three degrees of maturity is desirable (see also Chap. VII for size grades for ripe olives).

Pickling Vats.—Olives are pickled in shallow vats, usually constructed of concrete. These are generally about 8 by $2\frac{1}{2}$ ft. and about $2\frac{1}{2}$ ft. in depth. Circular or rectangular redwood tanks are also used, but concrete vats are less liable to become moldy or infected with bacteria and are more easily cleaned. The wooden tanks, however, are portable, and their use makes it possible to utilize the floor space in the pickling room for other purposes after the pickling season is completed. In most factories the vats are supplied with three overhead pipe lines, one containing water, one dilute lye solution, and one dilute brine. In some factories a fourth pipe line conveys compressed air to the vats. The vats are equipped with outlets for discharge of spent lye, brine, or wash water into open floor drains (see Fig. 32).

First Lye Treatment.—During the pickling process the olives are subjected to several applications of dilute lye. The first application is for the purpose of intensifying the color and not for the purpose of removing the bitterness. The concentration of the first lye solution varies from $\frac{1}{2}$ of 1 per cent to 2 per cent, depending upon the variety and maturity of the fruit and the pickling process. The usual concentration for the Mission and Manzanillo varieties is from 1 to $1\frac{1}{2}$ per cent, which corresponds

approximately to $1\frac{1}{4}$ to $1\frac{3}{4}$ oz. of granular 95 per cent sodium hydroxide per gallon of water.

Duration.—In most factories the lye is allowed to remain on the olives until it has penetrated the entire skin of the fruit but not long enough to penetrate more than $\frac{1}{16}$ in. into the flesh. In many plants the first lye solution is allowed to penetrate to about one-fourth of the olive

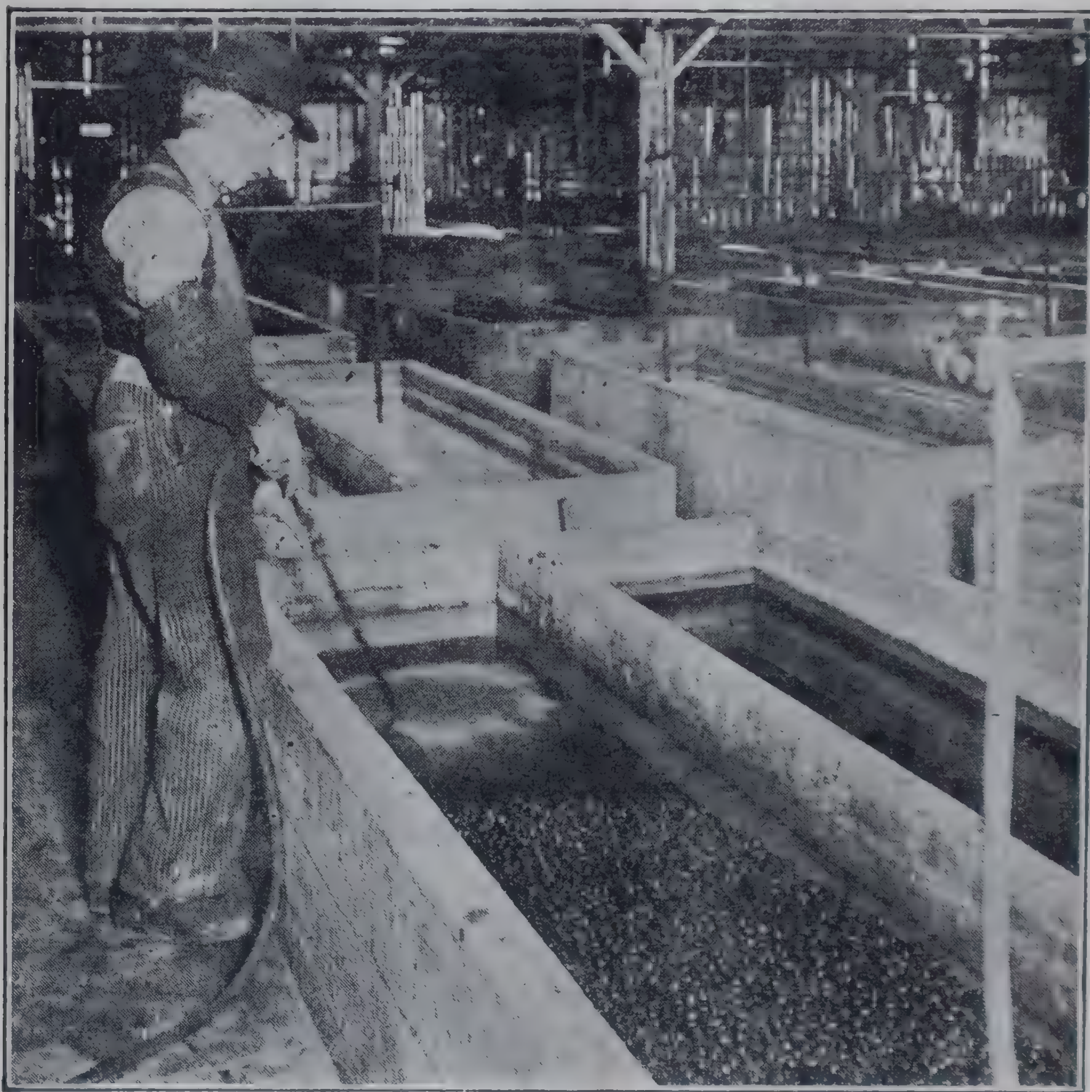

Fig. 32.—Pickling room showing concrete vats and method of stirring olives with compressed air.

skins. The color of the Sevillano and Ascolano varieties is very much more sensitive to the action of the lye than that of the Mission. For this reason more dilute solutions are used for these varieties.

Temperature.—The rate of penetration is affected by the lye concentration and by the temperature, increase of either causing increase in the rate of lye penetration. The temperature of the water in most plants is from 45 to 65°F. At this temperature range and with the use of a $1\frac{1}{2}$ per cent lye solution, the lye will usually penetrate the olives to the desired depth in less than 6 hr. Where the temperature is less than 60°F., the lye solution should be heated to 60 to 65°F. before application. Some of the olive picklers prefer to use a more dilute lye solution, *e.g.*, of from $\frac{1}{2}$ to

¾ per cent sodium hydroxide, and to allow this to remain on the olives for 24 hr. Experience demonstrates, however, that the stronger lye penetrates the olives more uniformly than do the more dilute solutions. The principal objection to the use of strong lye solutions is that they may cause bleaching of the color of the olives if allowed to remain on the fruit for too great a length of time.

Exposure to Air.—The progress of the lye penetration can be followed by placing a drop of dilute phenolphthalein solution on the cut surfaces of the olives or by noting the discoloration of the flesh caused by the lye. When the skin of the entire fruit has been well penetrated, the lye is removed and the fruit exposed in the vats until black or dark brown in color. Preliminary investigations indicate that the olive contains tannins of the catechol group and that the darkening process is probably very similar to the darkening of pyrogallol in dilute alkalies.

The usual length of exposure is 2 to 3 days. During this exposure to the air the olives must be stirred three or four times daily in order that the darkening may be uniform. If this is not done, air is excluded from the surface of the olives at points of contact between the individual fruits, and this area remains lighter in color than the fully exposed surface, resulting in a spotted or mottled appearance. The usual method of stirring the olives is to cover them with water and to agitate the liquid with compressed air for 2 or 3 min. Or the olives may be covered with water and stirred by means of a wooden paddle. The compressed air is less liable to cause bruising (see Fig. 32).

Other Methods of Darkening the Color.—In several large factories the olives are not exposed to the air following the first lye process but are covered with water, and the water is thoroughly aerated by means of compressed air, delivered to the vats through perforated pipes placed in the bottoms of the vats. The oxygen of the air dissolves in the water to a sufficient concentration to cause darkening of the fruit.

The flesh of the olives darkened by the aerated water process is generally lighter in color than that of olives darkened by exposure to the air. A pickled olive of light-colored flesh and dark skin is considered superior to one of dark skin and dark flesh.

Subsequent Lye Treatment.—In most commercial olive pickling plants the olives receive 4 or 5 or more treatments in dilute lye after the first lye treatment and exposure. These subsequent lye solutions usually contain about ½ per cent sodium hydroxide and are usually prepared in progressively decreased concentrations. After each addition of lye the olives are exposed to the air or treated with aerated water to further intensify the color. In a few factories two lye solutions only are used, the first solution to permit oxidation and the second to remove bitterness.

Regardless of the number of lye solutions employed, the last lye solution is used for the purpose of destroying the bitter principle. Therefore it is customary to allow this last lye solution to penetrate to the pit of the fruit.

In some commercial plants the strength of this last lye solution is not sufficient to destroy all the bitterness, and the pickler often relies upon leaching out the bitterness with water, following the last lye treatment. However, a better flavor is obtained if the last lye solution is of sufficient strength to destroy the bitterness. If it consists of ½ per cent sodium hydroxide, it will, in most cases, remove all trace of bitterness if allowed to penetrate completely to the pit.

The lye penetrates most rapidly at the stem end of the fruit, and it frequently happens that the blossom end of the fruit will remain bitter, while the stem end will be free from bitterness. If the lye action is too prolonged, the stem end of the fruit may become bleached in color. It is therefore necessary to note carefully the depth and rate of lye penetration in order that the quality of the fruit may not be injured and also in order that all the bitterness may be removed.

It is not possible to give the length of time of application of these various lye solutions. In most cases a very dilute lye solution, *e.g.*, ¼ per cent, is allowed to remain on the fruit for 24 hr.; a more concentrated solution, *e.g.*, ½ per cent, is allowed to remain on the fruit for 3 or 4 hr. only during each application. Also the length of exposure between these subsequent lye treatments cannot be given definitely. The usual time between treatments is, however, 24 hr., except between the first and second solutions, the olives being aerated between each two lye treatments.

Removal of Lye.—Following the last lye treatment the olives are leached with water until they no longer contain either sodium hydroxide or bitterness. The water is changed frequently, at least twice daily, and is stirred frequently by means of paddles or compressed air. It usually requires from 5 to 7 days' treatment to remove all of the lye from the fruit. If, however, the olives are stirred continuously with compressed air, it is possible to leach the lye from the fruit in much less time.

Effect of Temperature.—Water at 75°F. will remove the lye approximately twice as rapidly as water at 60°F. Although the higher temperatures cause more rapid solution of the lye from the fruit, their use is not advisable for the reason that the growth of bacteria is favored; very frequently fermentation and softening of the fruit occur in factories in which the temperature of the wash water is above 70°F. However, a temperature of 120 to 140°F. prevents fermentation and greatly hastens extraction of the lye.

Spoilage and Pasteurization.—At 70 to 75°F. "floating," fermentation, and softening may be very rapid and cause severe losses. Experiments made by the writer in 1921 and 1922 have demonstrated that such spoilage of the olives can be checked by heating to 175°F. for 30 min., should any evidence of fermentation occur. The heating must be done very carefully in order that the flesh of the olives shall not be broken by contact with jets of steam or by too violent agitation. The most convenient means of heating the water is by a portable steam siphon placed above the vat. Another method of heating the olives in the factory con-

FIG. 33.—Size grades for California ripe olives. Established by the California Olive Association.

sists in drawing off the water from the vat, heating it to the boiling point, and returning it to the olives until the desired temperature is obtained. One heating of this sort is usually sufficient to check fermentation and softening.

In addition to the fermentation and softening effects, the bacteria injure the flavor and exert a reducing action, evidenced by the fact that the color of the olives becomes bleached and will reappear if the olives are given a light lye treatment and are then exposed or aerated. In severe cases fisheye-like blisters are formed beneath the skin, giving the name of fisheye spoilage to this form of deterioration. Research by Tracy of this laboratory showed the organisms to be of the *Bacillus coli* and aerobacter groups.

The progress of the washing process can be determined by applying a dilute solution of phenolphthalein to the cut surface of the olives, a 1 per

cent solution of this indicator in 95 per cent alcohol being satisfactory for the purpose. The taste of the operator is, however, a more delicate indicator of the presence of lye than is the phenolphthalein. Phenol red is a much better indicator, as pH can be judged by its use. Investigations by the writer have shown that the color of the olives bleaches during retorting in the cans at 240°F., if the pH value exceeds 8.0, and that the color is most permanent if the olives are washed until the pH value is about 7.5. This point can be determined by use of phenol red indicator applied to the cut surface or by hydrogen electrode placed in the expressed juice.

Curing in Dilute Brine.—After all of the lye has been removed from the fruit, it is stored in a brine of about 2 per cent salt (8° salometer) for about 2 days. The concentration is then increased daily until the brine reaches a concentration of about 3 per cent (12° salometer). The time usually employed in this treatment is less than a week. Two days' time should be sufficient and storage of the fruit for a longer period is dangerous, because softening, fermentation, and other bacterial troubles may arise. In some cases the brine is increased to 5 per cent (20° salometer), and the olives are canned in a more dilute solution. This procedure tends to yield a firmer olive and to obviate salt shriveling in the can.

Sorting and Grading.—The pickled fruit is passed over broad, flat belts and is carefully sorted and graded for color and quality. The bitter fruit, which can be recognized by its mottled color at the blossom end, is removed and returned to the pickling vats. The well-pickled fruit is usually graded to two or three degrees of color, *i.e.*, light brown, dark brown, and black. It is also graded again for size, because during the pickling process shriveled fruit becomes plump and increases in size and other changes in size take place. Some factories, however, do not make this second grading.

Canning.—On Apr. 17, 1922, The California Ripe Olive Association adopted the following sizes of cans as standard and it has been agreed that cans packed by the members of the Association shall contain at least the net contents of drained olives noted below.

	Ounce
No. 10 packers' can	68 (later reduced to 66)
Tall quart olive cans	19
Tall pint olive cans	9
Buffet can	5

The broken and soft fruit is sorted out and sent to the oil room (see Chap. VII for size grades of olives).

The fruit is packed into tall cans which are considerably different in appearance from the ordinary fruit can. The cans now used, as a

result of experiments in this laboratory, are lined with a protective enamel, in order to prevent bleaching of the color after canning. The sizes used most commonly are known as tall pints, tall quarts, and ordinary No. 10 and No. 1 tall cans.

The olives are heated in water a short time before they are placed on the canning tables so that the women who fill the cans may handle the fruit conveniently, as canning normally occurs during the cold winter months.

The fruit is inspected by the women at the canning tables in order to detect soft or bitter fruit that may have escaped the women at the sorting table.

The cans are filled by weight in much the same manner as other fruits. A hot brine of $2\frac{1}{2}$ to $3\frac{1}{2}$ per cent salt, *i.e.*, 10 to 14° salometer. is added. The brine is added boiling hot, in most cases, from an ordinary fruit syruper or from an open pipe.

Exhausting and Sterilizing.—The filled cans are exhausted a short time, from 4 to 5 min., at 200 to 212°F. The center of the can should reach a temperature of at least 185°F.

The cans are sealed and are then sterilized in steam pressure retorts at 240°F. for 60 min. This time and temperature of processing render the olives thoroughly sterile, and probably from the standpoint of spoilage, or possibly of botulism poisoning, the safest canned food on the market. The State Board of Health of California inspects the olive-canning factories frequently and requires that every factory retain a temperature chart of each lot of olives sterilized. Also the cans of olives of each individual retort load must be given an identifying code mark.

If olives are packed in glass the caps on the jars tend to leak during sterilization and cooling unless the processing is carried out in retorts filled with water under heavy air pressure. If air at 15 to 20 lb. pressure is admitted to the retort with the steam and the mixture is kept in active circulation by means of open pet cocks, it is possible to sterilize olives in glass satisfactorily.

If this is not done, the caps on the jars act as valves during the cooling process and allow the escape of steam, as during cooling the temperature of the atmosphere in the retort falls below that of the olives in the jars. Steam is generated violently around the pits of the olives and causes rupturing of the flesh. When the olives are later removed from the jar the fruit becomes pitted in appearance, an effect caused by atmospheric pressure over the areas above "steam pockets." However, the use of compressed air with the steam during sterilizing and cooling prevents this effect. Air and retorting in water must be used in a manner specified by the California State Board of Health.

Summary.—The various steps in the pickling of ripe olives may be listed as follows:

1. *Receiving* fresh fruit and grading for size and into three grades for color. Grading for color, optional. Smallest fruit is sent to the oil mill.

2. *Storage* in brine (holding solution) 6 weeks or longer to harden the fruit tissue and render the action of the lye more uniform. Solution recommended, 6 to 8 per cent salt (24 to 32° salometer). Use of holding solution is optional but is recommended.

3. *First lye* treatment to permit oxidation of the color. Usual concentration of first lye 1 to 1½ per cent, *i.e.*, 1¼ to 2 oz. per gallon. Allowed to penetrate skin but only short distance into flesh. Skins of some olives are not penetrated by the first lye.

4. *Oxidation of color* by exposure to air or by aeration of water or dilute lye solutions. Period of aeration usually 2 to 4 days.

5. *Additional lye treatments* with solutions of lower concentration than first lye solution, usually ½ to 1 per cent lye, *i.e.*, ½ to 1¼ oz. per gallon. There are usually two to four such additional treatments, the last of which is allowed to reach the pits of the fruit. Four such treatments with ½ per cent lye (¾ oz. per gallon) are recommended.

6. *Additional aerations* of usually 24 to 36 hours' duration are given between the lye treatments listed under 5.

7. *Washing* with repeated changes of water until lye is completely removed from the flesh of the olives. Normally about 6 days' washing is necessary.

8. *Curing* in dilute brine 2 to 6 days before canning. Brine usually 2 to 3 per cent salt (8 to 12° salometer). Two days recommended.

9. *Grading and sorting for color* into light brown, dark brown, and black color. Cull fruit is sent to oil mill.

10. *Canning and brining;* a hot brine of 2½ to 3½ per cent salt (10 to 14° salometer) is added. Enamel-lined cans must be used.

11. *Exhausting* at 200 to 205°F. for 4 to 6 min. and sealing.

12. *Sterilizing* in retorts at 240°F. for 60 min., followed by cooling.

OTHER CANNED OLIVE PRODUCTS

A product of rapidly increasing popularity is canned "home-process" olives, otherwise known as "green-ripe" olives and by other names. Ripe olives of the Manzanillo or Mission varieties (pink but not black in color) are treated with several successive lye treatments until the lye reaches the pits. In experiments in this laboratory three lye solutions were employed, the first being 1.5 to 1.65 per cent sodium hydroxide, the second 0.75 per cent, and the third 0.50 per cent. The olives are not permitted to darken between lye treatments.

The lye is removed by soaking the fruit in water changed two to three times a day. The olives are then stored in dilute brine 2 or 3 days and are canned as previously described for the usual process.

Green olives are also prepared and canned in this same manner. The canned product should be golden yellow in color. Olives of this type are sometimes known as "California Canned Green Olives."

Since it is difficult to remove the last traces of lye from the tissues of olives pickled in this manner, some packers add some hydrochloric acid

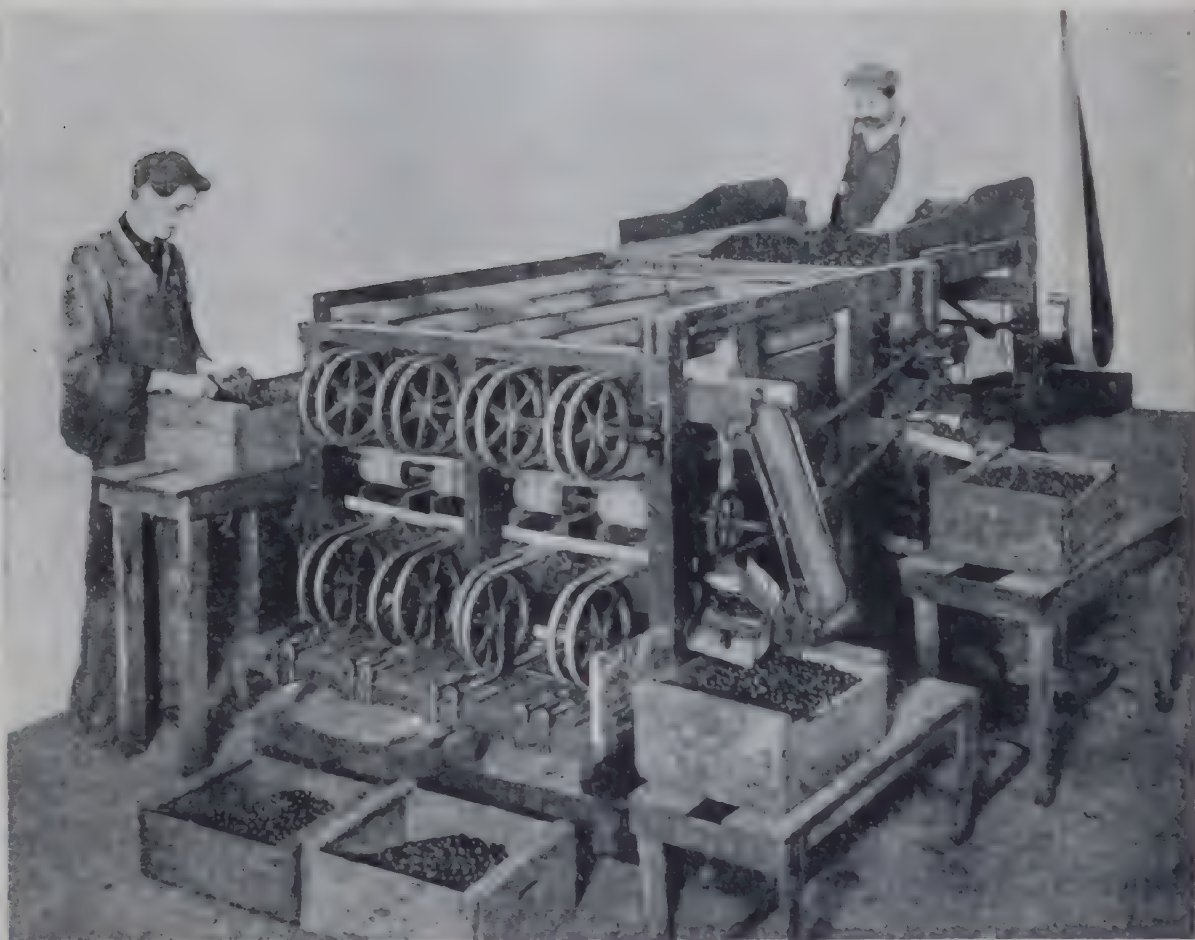

FIG. 34.—Grading fresh olives for size.

to the water applied to the olives immediately after the last lye treatment. In tests in this laboratory a solution of 0.25 per cent hydrochloric acid was applied until neutralized by the residual lye in the olives. Washing was then continued in the usual manner until near the end of the washing period, when sufficient 100-grain vinegar was added to reduce the pH value of the wash water to about 5.0. The last trace of lye can be removed also by pasteurization of the olives in water.

Chopped olives are procured by first preparing pickled ripe olives by the standard commercial process. The pits are removed by a machine operating on the principle of a raisin seeder, or the flesh is cut from the pits mechanically. The flesh is coarsely ground, flavored with salt (and a small amount of garlic and spices if desired) heated nearly to boiling,

canned hot in small key top cans, sealed, and processed at 240°F. for at least 70 min. Or the ground olives are canned cold, given a heavy exhaust in steam, sealed, and processed at 240°F. This product is used in sandwich spreads, mayonnaise, and for flavoring soups, meats, stews, etc.

Spanish Type Green Olives.—The Spanish process of preparing green olives is described in the chapter on pickling.

pH Control.—The pH value of olives (both regular, commercial ripe-process black olives and California home-cured or green-ripe olives) at time of canning is of very great importance. If the pH value is above 8.0, the color of California ripe-process olives bleaches during sterilization in the cans and the flavor of all types becomes scorched or "soapy."

It is therefore essential to continue the washing process until the pH value of the flesh or the expressed juice is below 8.0, preferably in the range 7.2 to 7.5. The expressed juice may be tested by means of a hydrogen or a glass electrode, a well-trained chemist being needed to make the determination. The cut flesh of several olives is quickly tested by applying a drop of dilute phenol red indicator and observing the color in comparison with a Clark's Hydrogen Ion Colorometric Chart (Williams & Wilkins Company, Baltimore). For ordinary plant control purposes the phenol red technique is satisfactory.

Since phenolphthalein changes from pink to colorless at about pH 8.1 or 8.2 or higher, it is not sufficiently accurate for the above purpose, although useful in detecting when most of the lye has been washed from the flesh.

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CHAPTER XIII

CANNING OF VEGETABLES

The annual output of canned vegetables in the United States is approximately twice that of canned fruits, although the value of the canned vegetables is only slightly greater than that of the canned fruits.

General Comparison of Fruits and Vegetables.—In general, we may consider canned vegetables as staple foods and the higher grades of canned fruits as dessert products. Vegetables differ from fruits in chemical composition and for this reason the processes of canning differ from those used for fruits. Most vegetables contain more starch than sugar as contrasted with fruits, which are high in sugar and low in starch.

The acidity of vegetables is generally much lower than that of fruits. Vegetables are grown in or near the ground as contrasted with fruits, which are grown generally on trees at a considerable distance from the soil. Vegetables, therefore, usually contain more of the resistant soil organisms than fruits and usually require more cooking than fruits to develop their most desirable flavor and texture.

For these reasons vegetables in general require a more severe processing than fruits in order to render them sterile and to cook them sufficiently for table use. Vegetables often contain disagreeable flavors or compounds which should be removed before canning and for this reason are usually blanched before they are filled into the cans. This is not necessary with most fruits.

Vegetables are grown as annual field crops, and this makes it possible for the canner to contract for each year's supply of corn, peas, or tomatoes in the current year, and to a very large degree he can plan to control the amount of his seasonal pack.

Raw Products.—The demands of the canner have developed the varieties of vegetables most suitable for canning purposes. In general vegetables for canning purposes should be uniform in color and quality, tender and in prime condition. Because of the rapid deterioration of vegetables after gathering, they should be transported from the field to the cannery in as short a time as possible, and for this reason the cannery should be located in or near the fields in which the vegetables are produced. This is particularly true of such quickly perishable vegetables as corn, tomatoes, spinach, and asparagus.

The cannery should arrange to plant the fields near the cannery in proper sequence, so that the produce will be delivered at a uniform rate over a long season.

Many canneries furnish the seed, or in some cases the small plants, to the growers so that they may be certain of obtaining the proper varieties for canning purposes. This is particularly desirable with tomatoes, peas, and corn.

ASPARAGUS

(Asparagus officinalis)

Most of the asparagus for canning purposes is grown in the delta lands of the Sacramento and San Joaquin valleys in California, and the largest canneries in this district operate their own asparagus fields.

Cultivation.—The delta lands are especially desirable for the culture of asparagus for the following reasons: The soil is a peaty loam, which permits the stalks of the asparagus to develop without distortion and permits them to reach large size in a short growing period. During the growing season the stalks grow from 4 to 6 in. per day. The soil is very rich and at the present time requires no fertilizing. Most of these lands are lower than the surrounding slough and rivers, are protected by levees, and are watered by irrigation obtained by siphoning. Owing to the porous nature of the soil, it may be irrigated from narrow ditches by subirrigation or lateral percolation, without the necessity of flooding the soil. This permits cultivation to obtain a light dusty mulch which protects the ground from baking and "crusting."

Harvesting.—During the first few weeks of the season the stalks are allowed to develop about 6 to 10 in. above the surface of the soil and for eastern shipment as green asparagus are cut to a length of 10 to 12 in.

Cutting.—Until rather recently only white asparagus was canned in California. A few years ago, owing to the increased popularity of the all-green asparagus in the fresh vegetable markets, several canners placed a moderate quantity of the canned all-green asparagus on the market as an experiment. It was an immediate success and at present all commercial canners pack it. It is rapidly overtaking the canned white asparagus in popularity. It is richer in flavor and vitamins than the white.

The green asparagus is allowed to grow through the surface to the necessary height. It is preferred, however, that the buds do not open to any great extent.

During the first 2 or 3 weeks of the cutting season, in late March and early April, most of the asparagus is shipped fresh to the local and eastern markets. When the supply exceeds the demand for the fresh asparagus, canning is begun.

White asparagus is cut beneath the soil. Workmen—usually Filipinos, Japanese, or natives of India—walk slowly along the rows, and where they see slight "bulges" of the surface soil or the protruding tip of a stalk, they insert a broad sharp chisel through the soil, cutting the stalk to a length of 8 to 10 in. They place the stalks in neat, small piles on the ridge of soil. Within a few minutes they are gathered up by

FIG. 35.—Upper left: Lug box of asparagus as received at cannery. Upper right: Cutting asparagus for cannery. Lower: Gathering cut asparagus.

another workman who places them in a horse-drawn box-like sled and takes them to the washing and cutting shed (see Fig. 35).

Washing and Trimming.—In order to prevent staining of the stalks by the drying on of adhering soil the stalks are rinsed thoroughly in water. They are then stacked in a shallow frame; pressure is applied by a wooden lever, and the stalks are cut to a uniform length of 7 to 8 in. The loss in trimming is said to be about 18 per cent.

Receiving.—The washed and trimmed asparagus is placed dripping wet in lug boxes; these are usually lidded to hold the stalks in place and are then promptly transported by truck or boat to the cannery. It is

essential that the asparagus be canned as soon as possible in order that it may not become tough and bitter. At the cannery the asparagus is either taken at once to the sorting tables or is stored for a few hours in a cooled well-ventilated room.

Inspection.—The deliveries from the different growers are carefully inspected, the amount of blemished asparagus, butts, etc., is carefully determined, and the weight of the asparagus unsuitable for canning is deducted from the amount delivered by the grower. It was formerly a common belief that California white canned asparagus was artificially bleached by sulfur fumes or other chemical means, but this is not the case. The white color is obtained by cutting the asparagus before it protrudes from the ground.

Grading.—The stalks are carefully graded by hand by women, who separate the stalks into as many as 11 different grades into 3-lb. boxes. The basis for grading is principally that of size, although the perfect stalks are separated from the imperfect and blemished stalks. The sizes usually made are given in Table 24. Mechanical graders are in use in some canneries but must be supplemented by much hand sorting.

TABLE 25.—SIZE GRADES FOR CALIFORNIA CANNED ASPARAGUS
(After Cruess and Christie's "Laboratory Manual of Fruit and Vegetable Products")

Size of can	Size grade	Number of stalks per can
No. 2½ square	Giant	8–12
	Colossal	13–16
	Mammoth	17–24
No. 1 square, tips	Mammoth	21–30
No. 2½ square	Large	25–34
No. 1 square, tips	Large	31–40
No. 2½ square	Medium	35–44
No. 1 square, tips	Medium	41–60
No. 2½ square	Small	45–60
No. 1 square, tips	Small	61–80
No. 1 square, tips	Tiny	81–100

These grades are made for both the white and the green stalks.

Cutting.—The boxes for the graded asparagus are 5½ in. deep for stalks which are to be placed in No. 2½ square cans, 4 in. deep for stalks to be placed in No. 1 tall cans, and 3 in. deep for the asparagus tips which are canned in No. 1 square cans.

The boxes of graded asparagus are conveyed by a belt to a table near a rapidly revolving circular knife. A workman holds the stalks against this revolving knife to cut them to exactly the lengths given

in Table 25. In some canneries all the butts are discarded and allowed to go into the sewer or river. A few canneries slice or shred the more tender butts and can the material for soup stock.

The loss in cutting is from 50 to 75 per cent.

Peeling.—A small quantity of the very largest stalks is peeled by hand with a guarded knife similar to that used in the peeling of pears, but the demand for peeled stalks is not large.

Blanching.—Asparagus contains considerable mucus-like material and is slightly bitter. Blanching removes these materials and at the same time softens the stalks so that they may be packed more tightly in the cans and permits straightening of crooked stalks.

The blanching operation is accomplished by placing the cut stalks in large wicker baskets which are transported through a tank of boiling water or by carrying the stalks through boiling water by conveyer. The blanching usually lasts for 3 or 4 min.

Filling the Cans.—The blanched asparagus is taken immediately to the filling tables, where it is placed in enamel-lined or stainless-steel sinks in water, where women carefully sort, wash, and pack it into the cans.

Cans.—The square can has proved the more satisfactory for the canning of asparagus for the reason that after exhausting, sealing, sterilizing, and cooling, the sides of the square can are drawn in and hold the stalks tightly together. This prevents them from moving and becoming broken during shipment.

Special can sealers were formerly used for the sealing of these square cans on which five separate and distinct operations were used in the sealing process. Sealing has been simplified now, and the modern sealer for square cans is similar to that used for cylindrical cans. Cylindrical cans are also used extensively.

Brining.—A hot dilute brine of approximately $2\frac{1}{4}$ per cent salt is added and in most cases a short exhaust is given before sealing.

Sterilizing.—The sealed cans are processed in retorts at 240 or at 248°F. under the supervision of an inspector of the Canning Inspection Division of the California State Board of Health. The official processing times and temperatures at present are, for white asparagus:

Size of can	Process temperature, °F.	Process time, minutes
(1) No. 1, No. 2, No. 1 square and No. 2½ square	240	24
(2) No. 10 cans	240	35
(3) No. 1 to No. 2½ square	248	12
(4) No. 10	248	15

For all-green asparagus they are:

Size of can	Process temperature, °F.	Process time, minutes
(1) No. 1 to No. 2½ square........	240	26
(2) No. 10......................	240	35
(3) No. 1 to No. 2½ square........	248	13
(4) No. 10......................	248	15

The cans must be processed in such manner that the spears are upright.

Yields.—Approximately 1½ cases of 24 No. 2½ cans each are normally obtained from each lug box of 50 lb. of freshly gathered asparagus. However, the yield will vary considerably according to the condition of the asparagus and the depth of cans used; the stalks are cut to much shorter length for the smaller cans in which tips are canned.

Blackening of Green Asparagus.—Often when a can of green asparagus is opened and allowed to stand for 30 to 60 min., the brine darkens and the color of the stalks ("spears") may also blacken owing to the formation of iron tannate. Iron is dissolved from the plate in the ferrous condition. After opening the can oxidation of the dissolved iron to the ferric condition ensues, in which condition it reacts with the tannin of the asparagus to give an iron-tannin ink of greenish-black color. If the stalks are cut before they have become too mature, there is little darkening.

Wiegand of Oregon Agricultural College has reported that addition of a small amount of citric acid to the brine used in canning will prevent most of the darkening. Citric acid has been used for many years for a similar purpose in white wines to minimize development of iron casse. See Chap. XXX.

Thermophilic Spoilage.—At one time considerable loss was incurred because of spoilage (often gaseous) of canned asparagus by thermophilic heat-resistant bacteria. By thorough washing to reduce soil contamination to the minimum and by use of more severe processing most of this form of spoilage has been eliminated.

GREEN BEANS

(Phaseolus Vulgaris)

While not so important as canned peas, the annual pack of canned green beans amounts to about 5,750,000 cases according to Geise. The beans should be of deep-green color, crisp and tender, fleshy, and as free from fiber and strings as possible. The Kentucky Wonder bean has proved very well adapted for canning purposes in California. The

Refugee or 1,000 to 1 variety is grown successfully for this purpose in the eastern and Middle Western states. Owing to the inroads of the mosaic virus disease of green pod beans, it has become necessary in the East and Middle West to develop, by selection and crossbreeding, mosaic-resistant varieties. Walker of Wisconsin Agricultural Experiment Station recommends the following: Michigan Robust, U. I. Great Northern, U. S. No. 5 Refugee, Wisconsin Refugee, and Idaho Refugee.

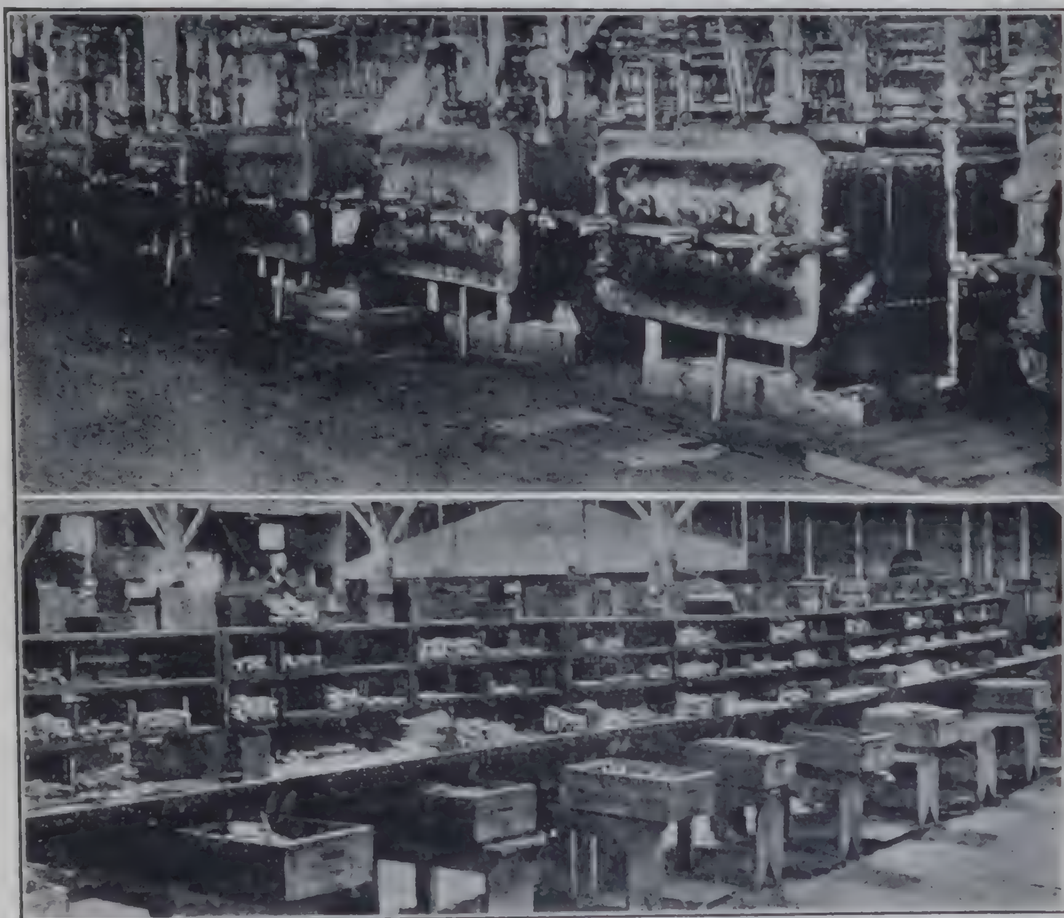

FIG. 36.—Lower: Asparagus grading tables. Upper: Retorts used in sterilizing canned asparagus.

Picking.—The pods of the beans for canning, except Kentucky Wonder, should be less than ¼ in. in diameter and less than 3 in. long, although those ¾ in. in diameter may be used.

They are usually delivered in sacks or in slatted crates and should not be placed in large stacks because sweating and bacterial action may ensue with great injury to the product.

Snipping.—The beans are trimmed or snipped by hand in most canneries, although attempts have been made to use an automatic snipping machine. At present, snipping machines leave much to be desired.

Grading.—In some canneries the beans are graded for size by means of rotating cylindrical graders and in others by hand. The largest grade is

cut into short lengths before canning, and the small sizes are canned without cutting. The usual size grades are: first grade, 8/64 in. in diameter; second grade, 11/64; third, 14/64; fourth, 18/64; and the fifth grade greater than 18/64 in. in diameter.

Blanching.—Following the snipping process the beans are thoroughly washed under vigorous sprays of water to remove adhering soil. They are then blanched either in boiling water or in steam, the period of treatment varying from 3 to 10 min., according to the size and maturity of the beans.

The usual blanching machine consists of a cylindrical screen equipped with a spiral conveyer, which carries the beans through boiling water. The blanched beans are cooled on a wire-cloth conveyer under sprays of cold water, which in addition to cooling the beans remove the slimy coating.

Canning.—The better grades of uncut beans are filled into the cans by hand, while cut beans may be filled into the cans by automatic filling machines similar to those used for peas. A brine of 2½ per cent salt is added boiling hot, and the cans are exhausted for 4 to 6 min. in live steam. Many Kentucky Wonder beans are packed asparagus style by use of a form devised by A. Greco of San Jose in 1918. The beans are cut to the length of the can; they are placed in a cylindrical form that opens in clamshell fashion; they are then compressed and forced into the can.

Processing.—The National Canners' Association recommends the following process temperatures and times:

1. Green beans and wax beans, whole or cut:

Size of cans	°F.	Minutes
No. 1 to No. 2 cans	240	20
No. 2½ and No. 3 cans	240	25
No. 5 cans	240	30
No. 10 cans	240	35

2. Green and wax beans, asparagus style:

Size of cans	°F.	Minutes
8-Z tall cans	240	25
No. 1 to No. 2 cans	240	30
No. 10 cans	240	40

Yields.—Approximately 70 to 80 cases of 24 No. 2 cans are obtained per ton of beans as delivered at the cannery.

"Stringless" Beans.—Certain pod beans have very prominent fibrovascular bundles and deserve the name of "string beans." However, young tender pods of certain other varieties are practically stringless and in preparing them for canning the ends need only be trimmed off; stringing may be dispensed with. This is particularly true of some varieties of Refugee beans. The label "stringless," unfortunately, is sometimes placed on cans of beans that are decidedly "stringy." "Stringiness" is probably nearly as dependent upon method of growing as upon variety.

WAX BEANS

Wax beans are similar in general properties to green pod beans except in color. The methods of preparation and canning are similar to those used for green beans. Sorting must be more carefully done, however, as blemishes are more conspicuous on the wax beans.

BROCCOLI, BRUSSELS SPROUTS, CAULIFLOWER, AND CABBAGE

These are common fresh winter vegetables available throughout most of the year in fresh form. However, some broccoli and "sprouts" but very little fresh cabbage is canned. Cabbage is usually converted into sauerkraut before canning (see chapter on Pickling).

Broccoli for canning is usually grown in a cool climate such as coastal sections in California or the cooler valleys of Oregon. Wiegand of Oregon Agricultural College recommends that the broccoli be trimmed, soaked in cold dilute brine for about 24 hr., blanched in dilute boiling brine about 3 min., chilled in water, canned in No. 2 cans, exhausted, and processed at 240°F. for 30 min. It resembles sprouts in flavor but is like asparagus in appearance.

Sprouts are broken from the head, sorted, blanched about 4 min. (preferably in dilute sodium bicarbonate), chilled thoroughly in cold water to prevent matting in the can, canned in dilute brine, exhausted thoroughly, and processed at 240°F. for 20 min. in No. 2 cans or 25 min. in No. 2½ cans.

Cauliflower is handled in a manner similar to that for sprouts except that it is advised that the "curds" be blanched in boiling dilute citric acid to prevent "graying" of the color in the cans. The National Canners' Association recommends processing 20 min. at 240°F. for Nos. 1, 2, and 2½ cans.

Cabbage may be trimmed, cut into sections, steamed until tender (steaming is preferable to a water blanch as less of the soluble food values is lost), canned in dilute brine of 1½ per cent salt, exhausted, and processed in No. 2½ cans at 240°F. for 40 min. or at 250°F. for 25 min. and in No. 10 cans at 240°F. for 60 min. or at 250°F. for 35 min. In order to

arrest cooking after removing from the retort the cans must be cooled very promptly and thoroughly.

CARROTS

(Daucus carota)

There is some demand for canned diced carrots for use in salads, stews, and soups or as food for cats and dogs. A considerable quantity of carrots is canned mixed with peas.

Small tender carrots are preferred. They are trimmed and sorted and then peeled either in a mechanical, abrading type of potato peeler, or in boiling dilute lye solution, washed, diced by mechanical dicer, canned in dilute brine, exhausted in the usual manner and processed in No. 1 to No. 3 cans, inclusive, at 240°F. for 25 min. or at 250°F. for 15 min. Number 10 cans are processed at 240°F. for 45 min. or at 250°F. for 25 min.

LIMA BEANS

(Phaseolus lunatus)

Green Lima beans are canned after being shelled from the pods. The bush variety is grown for canning purposes and is handled in much the same manner as peas.

Vining.—The vines are harvested when most of the beans have reached the stage of maturity most desirable for canning. The vines are passed through a pea viner, which threshes out the beans from the pods and separates the vines and pods from the beans, as described elsewhere for peas.

Grading.—The beans are cleaned in fanning mills and graded for size over screens having openings $^{24}/_{32}$, $^{30}/_{32}$, $^{31}/_{32}$, and $^{32}/_{32}$ in. in diameter. The various sizes are known as tiny, fancy, medium, standard, and mammoth. The smallest sizes are most tender, sweetest, and desirable for canning purposes.

The beans are placed in a tank of brine of such density that the green beans float and the overmature beans sink. Conveyers separate the two grades.

Before canning, the overmature beans are soaked in water until plump and are canned as "soaked Lima beans."

Blanching.—The green beans are blanched in boiling water in much the same manner as described elsewhere for peas. They are filled into cans by automatic fillers, and dilute brine is added. The proportion of beans and brine is such that the can will be well filled after processing.

Sterilizing.—The cans require no exhaust if filled with hot beans and brine. The process is, for cans up to and including No. 2 cans, 240°F. for

45 min. or 250°F. for 20 min.; for $2\frac{1}{2}$ cans, 240°F. for 60 min. or 250°F. for 50 min.; and for No. 10 cans, 240°F. for 70 min.

CORN

(Zea mays)

The canning of corn is one of the most important of the vegetable canning industries, the average annual production being approximately 10,000,000 to 24,000,000 cases, the output in 1935 being 21,471,000 cases. The most important corn-canning states are Illinois, Indiana, Iowa, Maine, Maryland, Minnesota, Michigan, and Wisconsin. Corn is packed in a number of other states of the Middle West and East but very little is canned in the Southern States and none is canned on the Pacific coast.

Production Statistics.—The output of canned corn varies considerably from year to year, largely because heavy plantings follow years of high prices and light plantings follow years of low prices. Some of the variation noted in Table 26 is due also to variation in yields per acre.

TABLE 26.—PRODUCTION OF CANNED CORN 1905 TO 1935
(*After The Canning Trade Almanac*)

Year	Cases of 24 No. 2 cans	Year	Cases of 24 No. 2 cans
1905	13,018,665	1916	9,130,000
1906	9,136,960	1917	10,803,000
1907	6,654,044	1918	11,721,860
1908	6,784,000	1919	13,550,000
1909	5,787,000	1920	15,040,000
1910	10,063,000	1921	8,843,000
1911	14,337,000	1925	24,320,000
1912	13,109,000	1930	15,692,000
1913	7,283,000	1933	10,192,000
1914	9,789,000	1935	21,471,000
1915	10,124,000		

The relative packs of the more important corn-canning states are given in Table 27.

Varieties of Corn for Canning.—Sweet corn varieties only are suitable for canning, and field corn should not be used. The kernels should be sweet and tender and of good flavor and cooking quality.

Sweet corn is of two classes: one in which the kernels are arranged in regular rows and the other in which the kernels are arranged irregularly on the cob. Stowell's Evergreen and the Country Gentleman are representative of the respective types.

The Country Gentleman variety possesses smaller kernels than the Evergreen and is generally of better canning quality. The four most important varieties are Golden Bantam, Crosby, Country Gentleman, and Stowell's Evergreen.

Erwin of the Iowa Agricultural College (1920) compared the yields of several leading varieties of canning corn with the results given in Table 28.

TABLE 27.—COMPARATIVE CANNED-CORN PACKS OF LEADING CORN-CANNING STATES
(*After Canning Trade Almanac*, 1935)

State	Cases, 1920	State	Cases, 1935
Illinois	2,271,000	Illinois	4,786,881
Indiana	861,000	Indiana	2,310,006
Iowa	3,246,000	Iowa and Nebraska	2,784,962
Maine	1,588,000	Maine, Vermont, and New Hampshire	1,931,030
Maryland	2,217,000	Maryland and Delaware	1,780,288
Minnesota	643,000	Minnesota	3,363,148
New York	829,000	New York	1,151,908
Ohio	1,544,000	Ohio	1,460,856
Delaware, Pennsylvania, Missouri, Michigan, Vermont	764,000	Wisconsin	955,853
		Other states	946,485
Wisconsin	590,000		
Other states	487,000		
Total	15,040,000	Total	21,471,417

Culpepper and Magoon studied the relative merits of a number of sweet corn varieties for canning purposes. They list, among others, Crosby, Potters Excelsior, Narrow Grained Evergreen, Country Gentleman, Stowell's Evergreen (white varieties), Golden Bantam, Morse's Golden Cream, and Vaughn's Bantam Evergreen. The Golden Bantam is a popular variety for whole grain corn in brine and for brineless whole kernel canned corn.

Styles of Canned Corn.—Most canned corn is packed in No. 2 cans and usually in one of two styles known in the trade as "Maine style" and "Maryland style," respectively. Maine-style corn is obtained by cutting through the kernels, scraping the remaining portions of the kernels from the cobs and mixing the scrapings with the cut kernels. Enough water flavored with salt and sugar is added to give the desired consistency. The product is creamy in texture when the can is opened and is the more popular of the two styles.

TABLE 28.—COMPARATIVE YIELDS OF SEVERAL VARIETIES OF CANNING CORN
(*After Erwin*)

	Yield tons per acre		Per cent of		
	Snapped corn	Cut corn	Husks	Cob	Corn
Early varieties:					
Lambert's Early	4.97	1.48	34.9	34.0	31.1
Early Crosby	4.87	1.23	37.6	26.2	25.2
Early Evergreen	3.98	1.16	31.5	39.5	29.0
White Evergreen	4.19	1.15	32.5	40.0	27.5
Main season varieties:					
Narrow Grain Evergreen	5.02	1.47	34.7	35.6	29.2
Stowell's Evergreen	4.78	1.53	27.5	39.9	32.5
Buena Vista	4.50	1.59	38.0	36.7	35.3

Maryland-style corn consists of the whole kernels cut from the cob and canned in brine; the cobs are not scraped.

A third style is double-cut corn, from overmature corn or from large kernels obtained by cutting the corn from the cob and cutting the kernels a second time by special knives to produce a creamed corn effect.

Recently brineless whole-kernel corn, vacuum sealed in cans, has come on the market and has been very favorably received. The process was developed by Fitzgerald of the American Can Company and has been termed "geraldizing."

Culture and Harvesting.—Corn for canning is planted and grown in the same manner as field corn. Much of the seed corn for planting for canning purposes comes from Connecticut.

Maturity.—Corn is at its best for canning purposes only a very short time and soon passes from the sweet succulent stage to the hard, tough, starchy stage. Because corn tends to become tough and starchy rapidly, it is necessary to observe its growth frequently and to gather it when at its optimum stage of development. Planting different fields at proper intervals permits canning over a fairly long period. Magoon and Culpepper of the U. S. Department of Agriculture found that most varieties grown under Maryland conditions were best for canning between 19 and 24 days after the silks had formed on the ears.

Hauling.—In harvesting the corn one man drives the wagon or truck while another snaps the ears from the stalks and throws them into the bed.

Testing Maturity.—The proper stage of maturity is judged by the appearance and feel of the ears. L. V. Burton has developed a method of

determining the maturity of canning corn, which he believes is adaptable to purposes of cannery control and as a means of testing corn from growers to insure delivery in prime condition for canning. His method consists in dropping 100 whole kernels one at a time into a brine of known specific gravity. The percentage of kernels floating at this specific gravity is determined. It is possible for a given locality and given variety of corn to establish a standard for the percentage of kernels which float and for the specific gravity of the brine.

Burton made determinations of thickness of hulls, moisture content of hulls, crude fiber of hulls, and specific gravity of kernels of a large number of samples of Country Gentleman corn at different stages of maturity. He concluded that the thickness of the hulls and crude fiber in the hulls could not be used as measures of maturity. He found that the moisture content of the hulls of tough kernels was considerably below that of hulls of tender kernels. This relation is shown in Table 29.

Culpepper and Magoon have used a pressure tester to measure the toughness of the corn and thereby its fitness for canning. Canners merely test the toughness by pressure of the thumbnail—a simple yet very useful test.

Corn should be picked in the morning while it is cool rather than at midday or during the afternoon. It is then less liable to sour before husking and is more crisp and succulent than if gathered warm. It deteriorates in flavor and loses in sweetness by prolonged storage or delay in delivery, in addition to being in danger of undergoing souring by bacterial action.

TABLE 29.—MOISTURE CONTENT OF HULLS OF COUNTRY GENTLEMAN CORN
(*After Burton*)

Grade assigned by packer	Moisture content of hulls, per cent
Fancy	72.0
Extra Standard	71.8
Fancy	70.0
Standard	67.0
Substandard	57.2

Receiving and Storage.—On arrival at the plant the load of corn is first weighed and is then driven to the dumping shed. The wagon or truck is unloaded by hand or is driven onto a platform which tilts the front end upward, causing the corn to fall through a chute into a bin beneath the platform. Conveyers carry the corn from this bin to the huskers or to storage cribs. The storage floor should be enclosed to

prevent trampling of the corn and should be served with conveyers which take the ears to the huskers as required (see Fig. 38).

If most satisfactory results are to be obtained, the corn should be husked in the order in which it is delivered and upon the day on which it arrives at the plant. If stored in large piles it is apt to sweat and become sour through the development of bacteria. If it is to be stored overnight or longer, it should be arranged in small piles to permit of good ventilation.

Husking.—At one time corn was husked by hand for canning, but at present all of the large canneries use mechanical huskers.

FIG. 37.—A typical corn cannery, husking shed in foreground. (*Courtesy The Canning Age.*)

Conveying.—The mechanical conveying systems are very complex but so arranged that the corn is handled mechanically practically throughout the entire canning process.

Huskers.—There are several designs of husking machines, but all have one feature in common. This is a pair of rapidly revolving rubber or milled-steel rolls against which the ear is held and which catch the husks and remove them in much the same manner that wet clothes are carried through the rolls of a clothes wringer.

The husker is equipped with a knife which cuts off the butts of the ears and also removes most of the silk with the husks. The rolls are kept wet with a spray of water during operation to prevent fouling. The butts drop into an apron spout at the back of the machine and thence into the husk conveyer. The husked ears pass by way of an apron spout to the clean corn conveyer for sorting and trimming.

Bins.—A convenient and efficient method of delivery of corn to the huskers is by means of a long, narrow, inclined chute connecting with a bin above the husker to the feed table at the husking machine. The operator then has at all times a supply of corn in a convenient position.

The husking machines are usually arranged in long rows, and all huskers in the line deliver the husked corn to a single clean corn conveyer (see Fig. 38).

Precautions.—O. S. Sells has indicated several important precautions to be observed in the operation and care of husking machines. He recommends that the butting knives should be sharpened frequently, *e.g.*, twice daily, in order that the machine may work smoothly and without excessive use of power. The husker rolls should be properly adjusted at all times. He recommends that rubber rolls should be compressed ⅛ to ¼ in. at points of contact and more tightly compressed at the discharge end than at the feed end, since most of the husks pass through the rolls at the feed end. In order to remove the thin surface layer of oxidized hardened rubber, the rolls should be dressed or roughened before the start of each season. To obtain clean husking, the machines must be supplied with ample power so that the rolls do not stop for an instant when they first grasp the husks. A long belt is less apt to slip at this point of the husking operation than is a short belt. Because of the heavy duty imposed upon them, all working parts must be well oiled and at the end of the season the rolls should be wrapped in paper and the machines coated with oil to check rusting and weathering.

The capacity of most single husking machines is rated at 60 to 80 ears per minute and of double machines at 120 to 160 ears per minute.

The husks and trimmings, which comprise about one-third the weight of the unhusked corn, are good stock food and are either fed direct or made into silage and used during the winter months. Conveyers carry the waste to the husk pile or to the silo.

Inspecting and Trimming.—No husker yet devised does perfect work and a certain amount of rehusking and sorting by hand is necessary to remove black ears or those with smut.

Inspection should be done while the ears rest in a single layer on a slowly moving conveyer.

Silking the Corn on the Cob.—The husking machines and trimmers remove most of the silk. In some factories the husked ears pass through a silking machine equipped with revolving brushes and rolls, and the ears are carried forward through the brushes which remove nearly all of the silk and deliver the silked ears to the washing machine. Silking of the cob can be omitted if the work of the mechanical huskers and the trimmers is well done, and removal of silk can be deferred until after cutting of the corn from the cob.

Washing.—Washing of the corn before cutting is desirable, to remove dirt, dust, ear worm excreta, smut, and small pieces of husk and silk. There are two satisfactory methods of washing: one by means of the silker-brusher washer described above, and the other by means of a revolving cylinder or conical reel, similar in design and operation to the rotary tomato washer. It consists of an inclined revolving perforated or screen cylinder through which the corn passes under heavy sprays of water. According to Sells the washer should rotate at from 12 to 15 r.p.m.

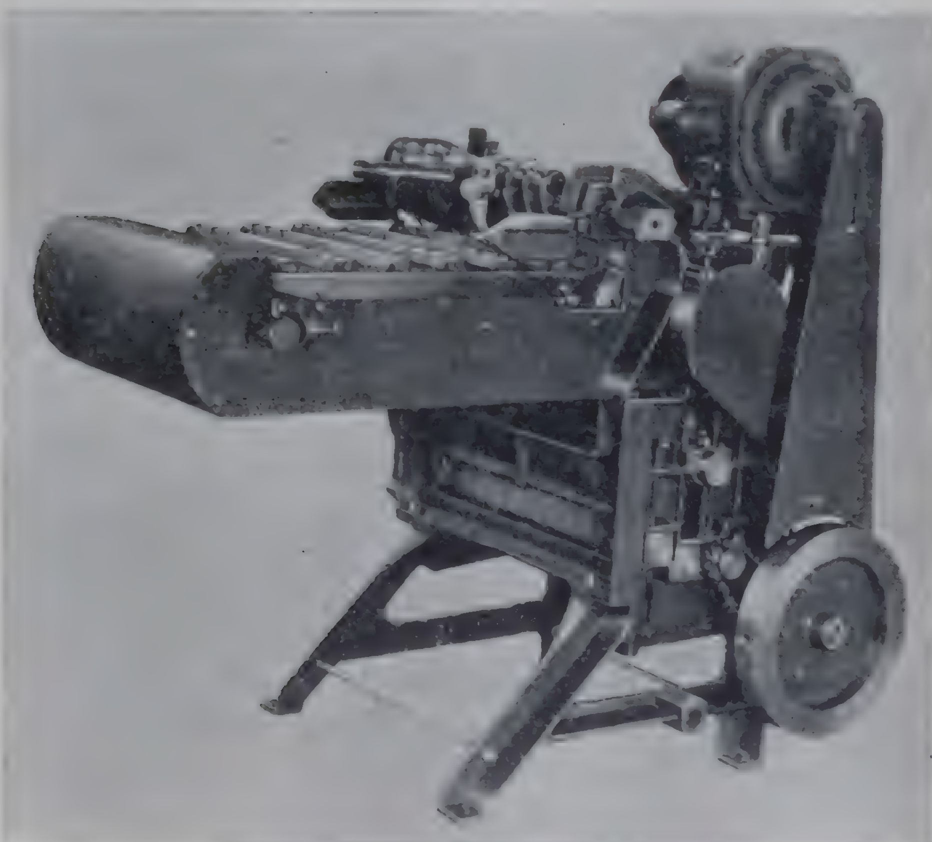

FIG. 38.—Large-capacity corn-husking machine. (*Courtesy Sprague Sells Machinery Corporation.*)

In tests made at the Agricultural Experiment Station at Ames, Iowa, it was found that a spray nozzle with a $^3/_{16}$-in. opening gave much better results than smaller nozzles, although more water was required. The increased efficiency, however, more than counterbalanced the increased water consumption. At 15 lb. nozzle pressure the spray was found to spread 13 in. at 18 in. below the nozzle; at 20 lb. pressure the spread was 15 in. and at 25 lb. 18 in. Seven nozzles, the usual number per washer, will use 189 cu. ft. of water per hour at 15 lb. pressure, 210 cu. ft. at 20 lb. pressure, and 231 cu. ft. at 25 lb. pressure. At least 15 lb. pressure per square inch at the nozzle is recommended.

The silker-brusher accomplishes practically the same results as the rotary washer, but it may be followed to advantage by spraying.

If the corn is washed immediately after husking and before sorting, a great deal of the labor used in sorting can be eliminated and trimming will be facilitated, because washing removes most of the silk, pieces of husk, smut, and worm evidence. In the rotary washer the ears are rubbed against each other vigorously, so that adhering dirt of all kinds is loosened and removed by the water sprays.

Some canners blanch the corn on the cob in water, at or near the boiling point to coagulate the juice, for corn to be packed as whole-kernel (Maryland) style.

Cutting.—During the early years of the corn-canning industry the corn was cut from the cob by hand, an expert cutter being able to cut corn for 1,000 cans per day in this manner. Some corn in small canneries is still cut from the cob by hand.

In 1882 the first mechanically operated cutter was invented by Sprague, a machine that has been improved upon but which has been the basis upon which the improved machines have been built. The knives were held under tension by rubber rings which adjusted themselves to the size of the ears, but rings required frequent replacement and later were replaced by metal springs. The circular head of this machine was later replaced by feed rolls having thin steel blades to force the ears into the cutter. This improvement resulted in more uniform cutting.

In the modern machine the ears are forced through circular knives which accommodate themselves by springs to the size of the ear. Scrapers beyond the cutting knives scrape the cobs for Maine-style corn.

Two sets of knives in tandem may be used to double cut the corn, the first pair of knives to cut about half of each kernel from the cob and the second pair to cut the remaining portion. This is done with overmature corn to improve its appearance and texture. For cream-style, *i.e.*, Maine style, corn part of each kernel is cut from the cob, and the remainder is scraped off the cob mechanically by blunt blades. The "scrapings" are mixed with the kernels.

The corn should be fed to the cutting machines small end first, as the knives adjust themselves to the ear more satisfactorily than if the butt end enters the knives first.

The cutter knives must be sharpened frequently, under normal operating conditions once every 5 or 6 hr., special grinders being used for this purpose.

The machines should be so arranged that working parts are readily accessible for repairs. Frequent oiling is necessary for smooth operation and clean cutting.

The cobs from the cutting machines are carried by a conveyer to the husk pie or to a cob crusher, where they are crushed or cut finely enough to be mixed with the husks for use fresh, for stock feed, or for siloing.

The cutting room should be well-lighted to permit inspection of corn and machines. It should have a sloping concrete floor to permit frequent "hosing down" and concrete walls to a height of 4 or 5 ft. for the same reason.

Silking the Cut Corn.—The cut corn is delivered by screw conveyers or by an elevator to the silking machine, which consists of a wire-screen cylinder which acts as a sifter and of a series of wire fingers that intermesh as the corn passes through. The fingers catch and remove the silks and

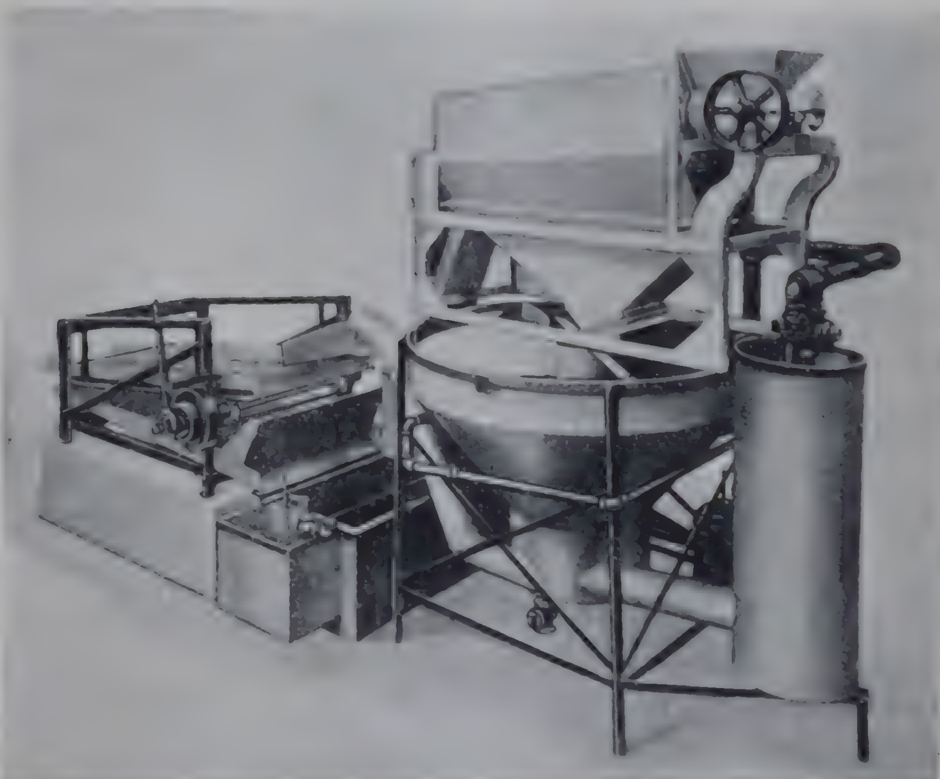

FIG. 39.—Corn- and pea-washing machine. (*Courtesy Sprague Sells Machinery Corporation.*)

the screen permits the corn to pass through, but retains pieces of husk or cob.

Mixing and Cooking.—The corn from the silker is delivered by conveyer to the mixer, where it is mechanically mixed with water, salt and sugar. Water must be added in order that the corn may not become a dry, tough mass in the can, the amount used varying with the maturity, variety, and method of cutting but according to Bitting will average about 5 oz. per No. 2 can. Early corn is apt to be more succulent than late corn and therefore usually requires less water. If less water is used on early corn, more salt and sugar per gallon should be added than where a relatively large amount of water is used.

Mixing must be thorough in order that the corn and brine may not separate in the can and that all cans may be alike in texture and flavor.

Brines.—Sugar and salt are added to give the desired flavor. These may be added with water in the batch mixer or are dissolved in the water

to give a sweet brine, which is then added to the corn in the mixer. According to Bitting, a larger proportion of sugar is used by eastern than by Middle Western canners, but a brine made up of 200 to 300 lb. of sugar and 75 to 100 lb. of salt per 500 gal. of water may be considered as normal in composition.

Cooker-filler.—From the mixer the corn is delivered to the cooker-filler, where it is heated to 175 to 190°F. before filling into the cans.

The cooker is heated by direct steam and is equipped with a mechanical stirrer. Too much brine gives a "sloppy" can and too little a dry product. Insufficient cooking leaves the corn and brine poorly mixed, or if mixed, the two will not be properly blended.

Temperature of Filling.—Usually the cooking device also fills the can with a measured amount of corn. It has been found by experience and experiments that the best results are obtained when the corn enters the cans at 180°F. If filled at temperatures below 180°F., there will not be sufficient vacuum in the can, and it will be subjected to undue strains in processing; if filled at too high a temperature, the cans may "panel," *i.e.*, be drawn in by atmospheric pressure because of the high vacuum. Filling at too high a temperature also results in a slack-filled can.

Cans.—Since corn is apt to blacken in plain tin cans by formation of iron sulfide, it is now customary to use cans lined with a special enamel containing zinc oxide. This enamel was discovered by G. H. Bohart of the National Canners' Association several years ago (see also Chap. XIV).

Sterilization.—Because of its high starch content and thick consistency, canned corn is a very poor conductor of heat. On this account and also because of its low acidity, it requires a high temperature and long period of processing.

Retorts.—Upright cylindrical retorts into which the cans are lowered in crates by means of a crane or steam hoist are generally preferred to horizontal retorts. The retorts are of smaller capacity than most horizontal retorts, which is an advantage, because it permits filling the retort quickly, thus preventing undue cooling of the canned product before the retort is filled. The usual corn retort holds approximately 900 No. 2 cans.

It is desirable that the retort be hot when the cans are placed in it, in order that cans in contact with the retort walls shall not be cooled. For the same reason the bottom of the retort should not contain cold water.

The cans should move quickly from the closing machines to the retort in order that undue cooling shall not take place before the cans enter the retort. Rough handling of the cans before or during filling of the retort should be avoided, because dented cans are apt to become leaky or buckled, with the development of "swells" or "flat sours."

Initial Temperature.—Bigelow and his co-workers have proved that the initial temperature of the can contents markedly affects the sterilizing effect of a given processing time and temperature, a can with contents at a relatively low initial temperature, *e.g.*, 120°F., requiring a much longer period to reach a sterilizing temperature than a similar can with contents at a relatively high initial temperature, *e.g.*, 190°F.

According to Harrison an increase of 2°F. in the initial temperature (at or about 180 to 200°F.) may be considered as equivalent to adding 1 min. to the processing time.

Time.—The usual temperature for processing cream-style corn in No. 2 cans is 245 to 250°F. At 250°F. a processing time of 70 to 75 min. is generally used, although in some factories to insure satisfactory keeping quality 90 min. at 245°F. is used. The National Canners' Association recommends not less than 80 min. at 245°F. The higher the temperature and the longer the period of processing the darker the color of the corn will be. Therefore canners are prone to process barely long enough to insure keeping of the product. Whole-kernel corn requires a less severe process than cream-style corn since heat penetration is more rapid. The recommended cook for whole-kernel corn in brine in No. 2 cans is 50 min. at 240°F. or 30 min. at 250°F.

Cans smaller than 2 are given the same processes as No. 2 cans of corn, either cream style or whole kernel. Number 10 cans of cream-style corn require about 180 min. at 240°F., or 160 min. at 245°F., or 145 min. at 250°F.

In all cases the foregoing times and temperatures are based on an initial temperature at the centers of the cans of 180°F. If below this initial temperature, the processing time must be increased correspondingly.

Processing times and temperatures have not been officially established for vacuum pack, brineless whole-kernel corn. Those contemplating this pack should consult a research laboratory of the canning industry, such as the National Canners' Association Laboratory, Washington, D. C.

Lethal Rate.—Bigelow and his associates have studied the resistance to heat of organisms causing the spoilage of corn and have based their recommendations for processing upon these data. Organism No. 26 required 214°F. for 1,180 min. for complete destruction of all spores in corn of a pH value of 6.1. Theoretically 1/1,180 of the spores were killed in 1 min. Bigelow designates this as the lethal rate, which he expresses as a decimal, in this case 0.0008. As the temperature increases, the lethal rate increases. Bigelow has determined the lethal rate at various temperatures and has given in Table 30 the temperature and the lethal rate at the center of a No. 2 can of corn in a retort at 250°F. at various intervals during processing and cooling. Much work on heat-resistant organisms has also been done more recently by Esty of the National Canners' Association.

Column 1 gives the time elapsing from start of heating process; column 2 the temperature at the center of the can; column 3 the time that would be required to destroy the spores at the temperatures given in column 2; and column 4 the lethal rate.

TABLE 30.—LETHALITY RATE FOR NO. 2 CANS OF CORN PROCESSED AT 250°F. Heating and Cooling

Indicated time, minutes	Corresponding temperature, degrees F.	Time necessary to destroy spores of Bigelow No. 26, minutes	Lethal rate
24.6	214.0	1,180.0	0.00080
29.5	220.0	756.0	0.00130
39.3	230.0	224.0	0.00456
53.0	240.0	70.0	0.01430
58.0	242.0	53.0	0.01890
64.5	244.0	42.0	0.02380
68.5	245.0	36.5	0.02740
74.0	246.0	32.0	0.03130
78.0	246.4	29.0	0.03440
78.0	246.4	29.0	0.03440
80.0	246.0	32.0	0.03130
81.5	245.0	36.5	0.02740
82.7	244.0	42.0	0.02380
84.0	242.0	53.0	0.01890
84.7	240.0	70.0	0.01430
88.1	230.0	224.0	0.00450
90.3	220.0	756.0	0.00130
91.7	214.0	1,180.0	0.00080

Similar data were obtained for other retort temperatures.

Equivalent processing times for various temperatures are given in Table 31.

Agitating Cookers.—With use of the agitating pressure cooker it is possible to increase the rate of heat penetration greatly and to use higher temperatures of processing than those now employed. A temperature of 260°F. has been used in an agitating cooker without injury to the color of the corn.

Retort Operation.—During the operation of retorts the bleeder valves should remain open to permit escape of air and to permit rapid and uniform heating of retort and contents. It is also desirable to heat the freshly filled retort with the safety valve or other large valve open, in order that the air may escape quickly. If one or two small cocks only are open during the period required to bring the retort to processing

temperature, the pressure gauge will show a pressure due largely to entrapped air and the temperature will be considerably below that which should exist for that pressure, and the processing may be much less effective than the canner has estimated it to be. Harrison reports an experiment in which the retort reached 250°F. in 4 min. with the safety valve open, whereas 15 min. were required with only the bleeder valves open.

The retort thermometer must be accurate if indicated processing temperatures are to be relied upon. The thermometer housing should be equipped with a bleeder cock so that the bulb is at all times surrounded by circulating steam, otherwise it may become surrounded by air and not indicate the temperature correctly.

TABLE 31.—EQUIVALENT PROCESSING TIMES FOR VARIOUS TEMPERATURES
(*After Bigelow*)

Process temperature in degrees F.	Time in minutes for sterilizing corn
260	56
255	64
250	78
245	96
240	129

Cooling.—The cans may be cooled in the retort by sprays of water or by repeatedly filling and emptying the retort with water.

In some corn canneries the cans are conveyed through a long shallow vat of running water either in crates or, more frequently, loosely. The retorts should be placed near the cooling tank in order that the crates of hot cans from the retorts may be emptied conveniently into the tank. Another method of efficient and rapid cooling is to cause the cans to roll beneath sprays of cold water. To the direct cooling by the water is added that of latent heat of evaporation of the water from the surface of the hot cans.

Owing to the danger from "stack burning" (scorching of the product through prolonged heating) or to the development of thermophilic bacteria in cans not sufficiently cooled, it is desirable to cool the cans to 110°F. or lower.

The cooling operation exerts some sterilizing action, and the higher the processing temperature the greater the sterilizing effect of cooling. If the cans are cooled rapidly, the percentage of sterilization that occurs during cooling and during heating for various retort temperatures is given in Table 32.

TABLE 32.—STERILIZING ACTION DURING HEATING AND COOLING
(*After Bigelow*)

Retort temperature, degrees F.	Sterilizing effect during heating period, per cent	Sterilizing effect during cooling, per cent
260	56	44
255	61	39
250	78	22
245	82	18
240	88	12

Cost of Canning Corn.—The average cost of canning 86,887 cases of corn in 21 different canneries is given by *The Canning Trade* at $1.268 per dozen. The items entering into this cost were as follows:

	Cost per Dozen	
Direct Factory Cost:		
1. Green produce	$0.324	
2. Seed loss	0.005	
3. Direct labor	0.114	
4. Cans	0.319	
5. Boxes	0.082	
6. Labels	0.017	
7. Condiments (salt and sugar)	0.065	
		0.926
Factory Overhead Expense:		
1. Factory expense	$0.131	
2. Depreciation	0.044	
		0.175
General Overhead Expense:		
1. Sales allowances and discounts	$0.024	
2. Interest and general expense	0.086	
		0.110
Brokerage and Selling Expense		$0.057
Total		$1.268

The cost of canning has varied since this survey but the relative costs of the different items will bear the general relation to each other given above.

Spoilage.—Canned corn may develop a black deposit owing to the formation of iron sulfide, a condition favored by the use of plain tin instead of enameled tin. Zinc oxide enamel, as stated previously, has solved this problem. It may become "flat sour" or develop gaseous spoilage because of insufficient processing or leaks. See Chap. XIV for more complete discussion of the spoiling of canned corn.

Standards for Canned Corn.—The U. S. Department of Agriculture standards for canned corn are as follows:

U. S. Grade A Fancy Cream Style corn must be prepared from young, tender sweet corn or corn of similar varietal characteristics. The color is bright and the product possesses a heavy cream-like consistency. It is practically free from defects such as presence of silks, husks, particles of cob, off-colored kernels, etc. The kernels have been cut neatly and uniformly from the cob and are in the early cream stage of maturity. The product possesses a flavor typical of succulent young corn, and scores not less than 90 points by the U. S. Department of Agriculture canned-corn scoring system.

U. S. Grade B (Extra Standard or Choice) canned, cream-style corn has similar specifications to those of Grade A except the word "reasonably" replaces "practically," the corn is in the cream stage and scores 75 to 89 points.

U. S. Grade C (Standard) cream-style corn is of somewhat poorer quality than Grade B, yet must be palatable, fairly free from defects, and score 60 to 74 points.

Off grade canned corn is that which scores less than 60.

The scoring system is as follows:

	Points
I. Color	5
II. Consistency	25
III. Absence of defects	20
IV. Cut	5
V. Maturity	25
VI. Flavor	20
Total	100

Detailed directions for arriving at scores for each property are given in the printed specifications, obtainable from the U. S. Department of Agriculture, Washington, D. C.

Similarly, grades have been set up for canned whole-kernel corn in brine (Maryland style). The scoring system is:

	Points
I. Color	10
II. Absence of defects	20
III. Cut	10
IV. Maturity	35
V. Flavor	25
Total	100

Minimum drained weights for cream-style and whole-kernel-style canned corn have been established. Cans that do not fulfill this requirement must be labeled "Below U. S. Standard. Slack Fill." If an exces-

sive amount of liquid has been added the label must state, "Below U. S. Standard. Slack Fill. Contains Excess Added Liquid." Cans of corn will be considered to be of "slack fill" if the head space, measured from the top of the product to the underside of the lid, exceeds 10 per cent of the total inside height of the can.

BEETS

(Beta vulgaris)

Beets for canning purposes must be small in size, of uniform deep red color, tender, and of good flavor.

Grading.—They are usually graded for size by screens into the following sizes:

Small (Rosebuds), less than 1 in. in diameter.

Medium, 1 to 1½ in. in diameter.

Large, 1½ to 2 in. in diameter.

Those that are larger than 2 in. in diameter are cut before canning. The grader used for beets is usually cylindrical and is equipped with wooden slats set at the proper distance apart to give the above grades.

Washing and Blanching.—Beets require soaking in water and thorough washing under sprays to remove adhering soil. To permit peeling, the washed beets are steamed in a retort at 220°F. for 20 to 25 min. Boiling water can be used to loosen the skins but it removes a considerable amount of the sugar and other soluble compounds.

Peeling and Canning.—The steamed beets are chilled in water and trimmed and peeled by hand. They are filled into lacquered cans by hand and a very dilute brine or water is added. In plain tin cans the color bleaches rapidly or becomes blue because of the reaction between tin salts and the color.

Processing.—Canned beets in No. 2 or 2½ cans are sterilized for approximately 25 min. at 240°F. Cut beets are packed in No. 10 cans for the use of restaurants and hotels and should receive a process at 240°F. of 45 min.

OKRA

(Hibiscus esculentum)

Okra is used principally for soups and is a staple garden crop of the Southern States where it is known in some localities as "gumbo." The pods resemble peppers in appearance and are rich in gums and probably pectin. The pods should be picked while still tender and before they have become fibrous and tough.

The pods may be blanched 1½ to 2 min. in water, the butts should be cut off and discarded, and the pod should be cut into sections crosswise

with a string bean cutter. The pods may also be cut in cross sections and canned without blanching. The National Canners' Association recommends a process of 17 min. at 240°F. for No. 2 cans and 20 min. for No. 2½ cans of okra.

PEAS

(Pisum sativum)

Peas were brought to America with the first immigrants and are now grown practically everywhere in the United States as a home-garden

Fig. 40.—Receiving platform in a large California cannery.

crop and for the fresh market, but they are grown even more extensively for canning.

Size of Industry.—The pack of canned peas is exceeded in normal years only by corn and tomatoes, and the value of canned peas sometimes exceeds that of corn. The canned product is relatively low in price to the consumer and is a food of attractive flavor and high nutritive value rather than a luxury.

The pack has increased from about 800,000 cases in 1885 to 24,698,000 cases in 1935.

As with corn, the production of canned peas has varied greatly from year to year according to whether the preceding year was one of under or over supply. This condition is shown in the following table:

TABLE 33.—CANNED PEA PRODUCTION
(*After Canning Trade Almanac*)

Total Production in U.S.A.		Production by states for 1920	
Year	Cases	State	Cases
1906	4,574,608	Wisconsin	5,804,000
1907	5,885,064	New York	2,381,000
1908	5,577,000	Michigan	549,000
1909	5,048,000	Indiana	271,000
1910	4,137,000	Maryland	696,000
1911	4,372,000	Ohio	282,000
1912	7,307,000	Delaware / New Jersey	549,000
1913	8,770,000		
1914	8,847,000	Utah	595,000
1915	9,272,000	California	328,000
1916	6,686,000	Illinois	460,000
1917	9,829,053	All others	402,000
1918	11,063,156	Total for 1920	12,317,000
1919	8,685,000		
1920	12,317,000		
1930	22,035,000		
1933	12,892,000		
1935	24,698,000		

When high prices for peas prevail, planting and canning are stimulated, often to the point of overproduction. Provided the peas are available for canning, the capacity of present pea canneries is more than sufficient to meet the normal demand.

The writer is of the opinion that more extensive advertising of canned peas and corn is required to stabilize the industry and create a healthy increase in demand. At the present time prices and production in both of these industries are subject to rather violent fluctuation. Also, there is need for devising a process of canning which will retain more of the color and flavor of the fresh peas. Canned peas have a greenish-yellow color; in contrast with the bright-green color of fresh, cooked peas or frozen-pack peas.

Historical Note.—At first peas were grown garden fashion, and picked and hulled by hand, but the cost of growing the crop and the excessive labor costs limited the output of the canneries and made the price of the product high.

Numerous attempts were made to invent mechanical hulling machines, but most of these were failures, since they were attempts to imitate mechanically the pressure exerted on the pods by the fingers. Rubber

rolls, revolving disks and other machines dependent upon pressure were of very limited capacity, did not hull perfectly and bruised the peas.

In 1883 Madame Faure in France invented a machine which hulled the peas mechanically by impact. Paddles revolving in a screen cylinder broke open the pods and the peas were separated by screening. Her invention was described in *La Nature*, Paris, in 1885, and a translation of her article appeared in the *Scientific American*, June 6, 1885. Shortly, thereafter a similar machine was built in America, was proved successful at Baltimore, and was rapidly adopted by commercial canneries.

Although Madame Faure's machine did the work of 100 hullers, the early American machines were somewhat larger. Scott and Chisholm were prominent in developing pea-hulling machines in America.

According to R. P. Scott, in the season of 1886 all peas were hulled by hand; in 1887 an appreciable quantity were hulled by machinery and in 1888 one-half of the output was so hulled.

The invention of the impact huller made it possible to move canneries away from the cities to the thinly populated producing sections and thereby greatly reducing costs of production.

In 1890–1892 the hulling machine was so modified that it became possible to thresh the peas from the pods on vines, which had been cut with a mower. Previous to this it was necessary to pick the pods by hand. This advance was of nearly equal importance with Madame Faure's invention.

Today peas are grown as a field crop by tractor cultivation, harvested by mowers or pea harvesters, hauled by truck to the viner, hulled mechanically, and taken at once to the cannery where they pass mechanically and more or less automatically through the operations of cleaning, blanching, filling, sterilizing, and cooling.

Climatic Requirements.—A cool summer climate with frequent rains or cloudy or foggy weather produces peas that are tender, sweet, and of good color. Wisconsin is the premier pea-producing state, largely because of the favorable climatic and soil conditions. Washington state, however, is becoming a close competitor.

At present New York, Washington state, and Wisconsin furnish 60 per cent or more of the entire pack, although Utah and the uplands of Colorado are also very suitable for peas.

Varieties.—Field peas have been classified as a different species from garden peas, but this distinction is being abandoned. Formerly field peas were classified as *Pisum arvense* and garden peas as *Pisum sativum.* At present both are classified as *Pisum sativum.*

For canning purposes, Shoemaker lists the following requirements: (1) The variety must be productive, a requirement which excludes dwarf types and includes the quality of hardiness. (2) All plants must

ripen uniformly. (3) All pods on each vine must be in usable condition at one time, *i.e.*, none must be too ripe or too immature. This requirement excludes varieties with too great length of vine. Bush vines, not climbing vines, are used. (4) The peas must remain green after processing, which eliminates yellow-seeded varieties. (5) High quality, *i.e.*, good flavor, texture, and small size are necessary.

The viner has made requirements (2) and (3) important. When the pods were gathered and hulled by hand, uniformity in ripening was not so necessary.

Peas for canning purposes are of two types, *viz.*, the early smooth-seeded varieties and the later and sweet, wrinkled-seeded varieties. The latter are of better flavor, but often do not produce so heavily as the smooth-seeded types. The most important smooth-seeded variety is the Alaska and the most widely used wrinkled-seeded varieties, the Horsford Market Garden, Advancer, and Admiral. Other improved varieties are used also.

The Food Administration in 1917 compiled data showing the relative importance of the different varieties as follows:

Type	Per Cent of Total Production
Smooth peas:	
1. Alaska	55
Wrinkled peas:	
1. Horsford Market Garden	18
2. Advancer	8
3. Little Gem	1
4. Perfection (Davis)	1
5. Admiral	13
6. Surprise	2
7. All others	2

The Alaska is a favorite with canners, because it is hardier and a more reliable producer than most of the wrinkled varieties. For this reason it is about the only variety used in the southern areas of the pea-canning region, including Maryland, Delaware, New Jersey, and the southern parts of Ohio, Indiana, and Illinois. This variety ripens early and retains its color well in processing.

Harvesting.—The time of harvesting is determined largely by the appearance of the pods, which should be swollen and well filled with young succulent peas which change in color from dark to light green.

The fields should be inspected before harvesting to remove vines of "off type."

The cannery agent sets the date of harvesting, and frequent inspection is necessary to make certain that the peas do not pass prime condition and become overmature.

An ordinary mower, equipped with vine-lifting guards attached to the cutter bar and a swather which bunches the vines in a neat windrow, is used. The vines may be loaded direct from the windrow onto trucks, or the rows may be bunched with a rake. In some cases automatic loaders drawn by a tractor can be used to load the trucks.

To avoid wilting, it is desirable to cut the vines in the morning or evening rather than in the middle of the day. Delay in vining results in deterioration in quality and may permit sweating and fermentation.

Vining.—Most of the shelling or vining is done at so-called vining stations, located in the fields. This avoids long haulage of the vines.

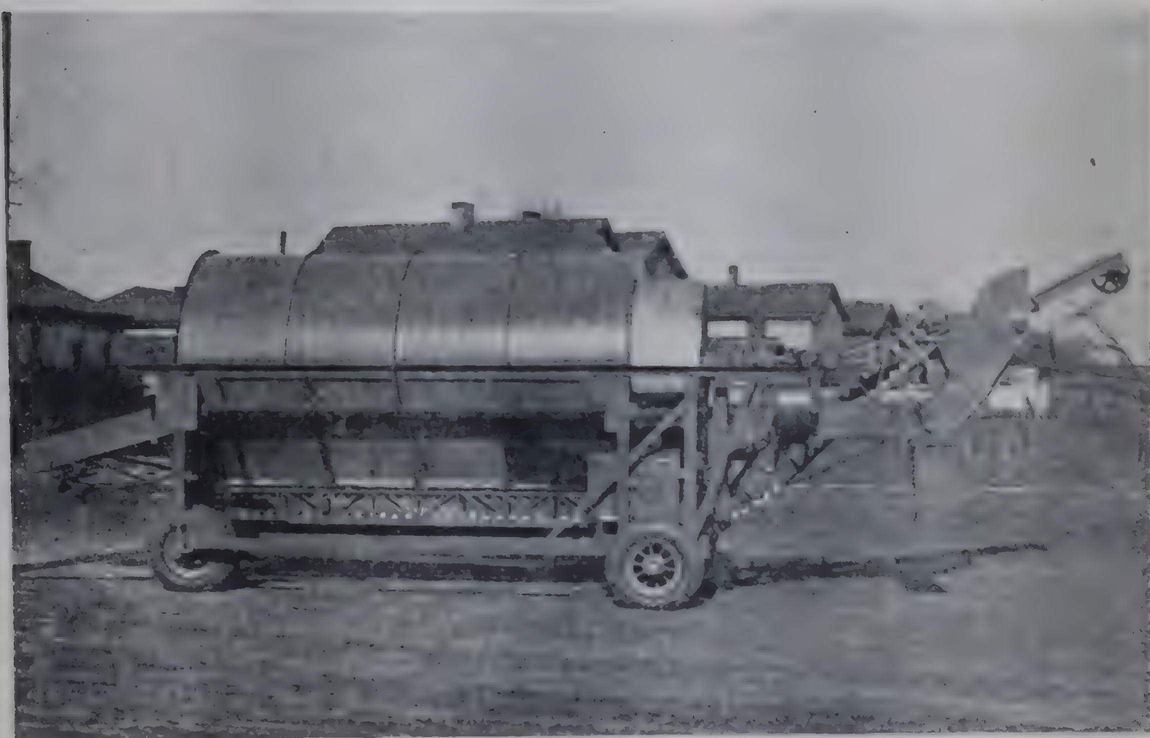

Fig. 41.—All-steel pea viner. (*Courtesy Scott Viner Company.*)

The vining machine consists of a perforated metal cylinder, inside of which are beaters on a central shaft. The cylinder revolves slowly, while the beaters revolve rapidly in the direction opposite to that of the cylinder. The peas are hulled by impact with the beaters and fall through the openings in the cylinder. The vines are carried through the cylinder and are delivered to a conveyer, which delivers them to a truck or to a silo. The beaters are pitched at such an angle that the vines are carried through the cylinder; the speed of the beaters and the pitch determine the time the vines remain in the viner. The peas drop through the perforated cylinder onto a slowly upward moving canvas belt to which leaves and pieces of pod stick while the peas roll down the belt into hoppers (see Fig. 41).

One viner is required for each 100 acres under average conditions. According to recommendations of the A. K. Robbins Machinery Com-

pany three viners will supply peas for one cleaner, one blancher, one filler, two closing machines, and five 40 by 72 vertical retorts. Each viner can do the work of 200 persons shelling peas by hand.

Yields.—The yield of shelled peas varies from nothing to 5,000 pounds per acre, but the average for the United States for a 4-year period, was 1,800 lb.

Cleaning.—At the factory the peas are first passed through a cleaner, which removes light pieces of pods or vine by a blast of air. The air-cleaned peas drop on to a large screen, which removes large pieces of pod, etc., and thence to a fine screen, which permits passage of fine dirt and splits but retains the whole peas.

In California sometimes a bur cleaner is used, consisting of a revolving carpet-covered roller to which clover burs stick. Thistles may be removed by flotation in water and skimming.

Size Grading.—The cleaned peas are graded for size through a long cylinder or through a series of nested cylinders having holes of the diameters given below. In the single-cylinder grader the smallest peas are removed first and in the concentric or nested grader the largest sizes are removed first.

Grade No.	Screen
1. Petite	9/32 in. diameter
2. Extra Sifted	10/32 in. diameter
3. Sifted	11/32 in. diameter
4. Early June	12/32 in. diameter
5. Marrowfats	13/32 in. diameter
6. Telephone	larger than 13/32 in. in diameter

Water Requirements.—About 15 gal. of water, used for washing, blanching, flotation, etc., is required for each case of peas canned.

Quality Grading.—In addition to grading for size the peas are also graded for quality. If the peas are placed in a tank of brine of the proper specific gravity, those of higher quality will float, and the starchy or inferior peas will sink. This separation is accomplished in automatic grading machines consisting of two tanks of brine through which the peas are carried by conveyers. According to Bitting the first tank is usually filled with brine of specific gravity of 1.04 and the second tank with a brine of a specific gravity of 1.07. The peas that float in tank No. 1 are known as Fancy and those which float in tank No. 2 are known as Standards. Those which sink in tank No. 2 are known as Seconds, or Substandards. There is a large percentage of Seconds among the larger sizes of peas, whereas most of the very small peas are of the Fancy grade.

Because of their high sugar content and deep-green color, the small peas command the highest prices. On account of their high starch content the larger peas tend to produce a cloudy liquor, in addition to being

less desirable in flavor and color. However, they are of lower moisture content and higher nutritive value.

Effect of Maturity.—If the peas are carefully grown and harvested at the proper stage of maturity, the percentage of large sizes will be low, although the yield per acre will not be as great as if the peas are allowed to reach a more advanced stage of maturity. Therefore, the canner must exercise great care in supervising the harvesting of the crop so that the growers will not allow the peas to become too ripe. The tendency on the part of the grower is to permit the vines to reach a more advanced

FIG. 42.—Spinach blancher, draper type. (*Courtesy Food Machinery Corporation.*)

stage before harvesting than the canner desires, in order to obtain the maximum yield.

The maturity of peas is judged by their starch content. A rapid and fairly satisfactory method of estimating this is determination of alcohol-insoluble matter (see U.S.D.A.). See Bonney and Rowe for details.

Sorting.—Following the mechanical grading operations, the peas are carefully sorted on broad belts to remove pieces of pod, etc.

Blanching.—Peas are blanched thoroughly to fix the color, to remove mucus from the skins, to improve the flavor, and to permit the placing of a larger weight of peas in the can. There is, however, considerable doubt that blanching fixes the color.

The length of blanching varies greatly with the maturity of the peas and may be as short as ½ min. for very small, tender peas and as long as 30 min. for large, starchy peas. Bigelow states that blanching does not soften overmature peas, but on the contrary hardens them.

If the peas have soured slightly between the shelling and the blanching processes, some add a very small amount of sodium bicarbonate to the blanching tank. Some canners believe that the addition of a small amount of soda intensifies the green color and that it should be used for the peas whether sound or sour in condition, but its use is

not general and is dangerous, since it increases the pH value and therefore danger of survival of spores of *Clostridium botulinum*. See also Chap. VI.

The usual pea-blanching machine is continuous in operation and consists of a screen or perforated cylinder with a spiral conveyer, which revolves in a tank of boiling water. The length of blanching is regulated by the speed of rotation (see Fig. 43).

The blanching water should be changed frequently in order that it may not become foul.

Washing.—The peas should be washed very thoroughly after blanching. The usual washer is a revolving screen cylinder with internal sprays.

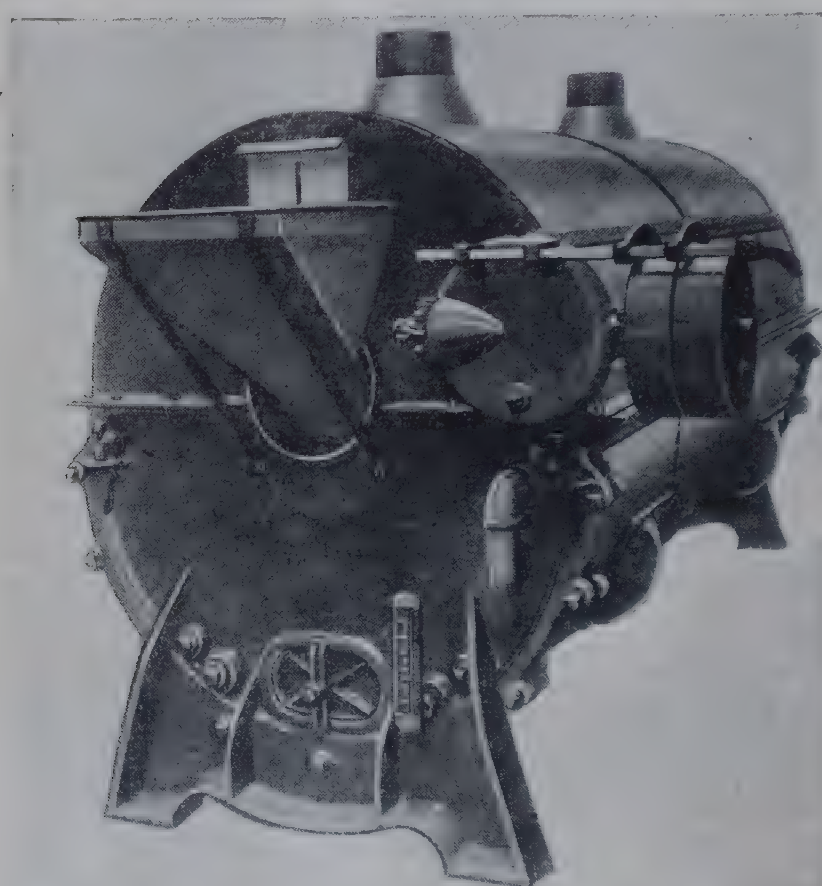

FIG. 43.—Pea blancher. (*Courtesy Sprague Sells Corporation.*)

Filling.—The peas are filled into the cans by automatic machines which deliver a definite volume per can. Generally, the peas are heated just before they enter the filling machine, a boiling hot brine is added and the exhausting of the cans is not necessary. In most cases the brine used in the canning of peas consists of a mixture of salt, sugar, and water. About 2 per cent of salt is used, and to the better grades from 2 to 5 per cent of sugar is frequently added. In a California cannery a brine of 22½ lb. of sugar and 18 lb. of salt per 150 gal. of water was used for the best grades and one of 31½ lb. of salt per 150 gal. for the poorer grades. A filling machine is shown in Fig. 44.

Storage.—If unblanched peas are not canned at once, they should be stored under dilute brine or water to avoid darkening and growth of bacteria; but storage or other delay is undesirable.

Processing.—Large, starchy peas require a longer process than the small, tender grades. At 240°F. 35 min. is usually regarded as a safe sterilizing schedule for No. 2 cans and 55 min. at 240°F. or 30 min. at 250°F. for No. 10 cans. Considerable losses from spore-bearing anaerobic bacteria have been encountered by the canners of peas in the Middle Western states. At the present time, however, sterilization processes are usually severe enough to destroy these organisms.

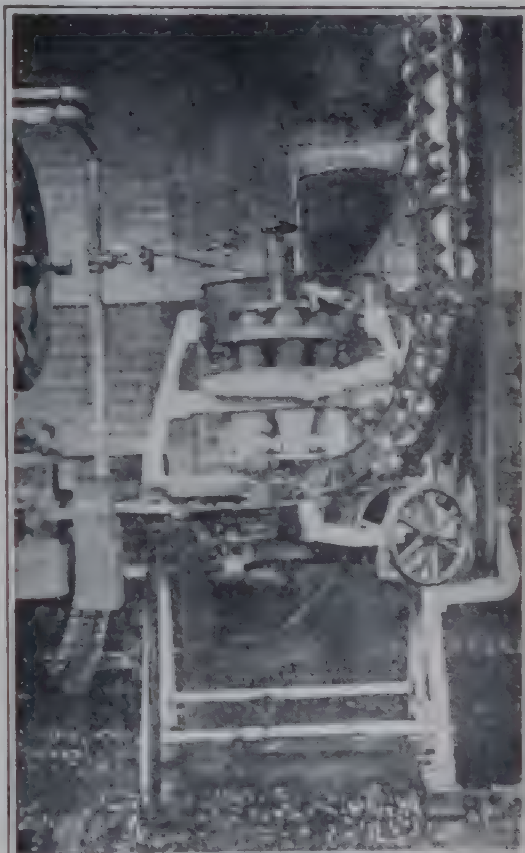

Fig. 44.—Can-filling machine for peas.

Cooling.—Cooling should be thorough and rapid following sterilization, to avoid excessive softening and the formation of a cloudy brine through gelatinization of starch.

Cutout Standards.—The normal net contents of a No. 2 can of peas is 20 oz., of which usually slightly more than 13 oz. consists of peas and the remainder of liquid. The Bureau of Chemistry, U. S. Department of Agriculture, has ruled that a No. 2 can must contain 13.5 oz. drained weight of peas.

Spoilage.—For discussion of spoilage see Chap. XIV.

Causes for Substandard Peas.—The canner desires to obtain the largest possible proportion of the best grades of peas, because therein lies the most profit. Bigelow has summarized the causes for substandard or low-grade canned peas as follows:

1. The use of a variety which does not ripen evenly, or of peas that have not been properly "rogued."
2. Lack of care as to time of harvesting, permitting too many peas to become overmature.
3. Allowing vines to stand too long after mowing, causing peas to ripen and harden.
4. Allowing peas to remain too long in boxes after being vined, caused by delay in hauling from viner or delay at factory.
5. Mixing of mature and immature peas in grading. During processing the mature peas swell and cause the pack to appear ungraded.
6. Permitting heating of the vines or hulled peas.

7. Excessive handling of unblanched peas, particularly in boxes. Smooth, perforated metal pails are preferable to boxes.

8. Underfilling or overfilling through lack of proper adjustment of the filling machine.

9. Improper cooling, injures color and gives cloudy brine.

10. Use of hard water in blanching. Causes peas to be hard.

11. Too strong brine. This causes toughness.

12. Too long blanch. Causes peas to be hard, contrary to popular belief—blanching does not make peas tender. Tenderness is imparted only in the processing.

13. Lack of judgment in varying the process to suit the character of the raw material.

Cost of Canning Peas.—The average cost of canning peas in 11 plants in Wisconsin and Illinois is given as follows by A. T. Bacon:

Average Unit Cost to Pack 1 Dozen No. 2 Cans of Peas

Direct Factory Cost:	
Green Product (including seed)	$0.379
Direct Labor	0.113
Cans	0.302
Boxes	0.074
Labels	0.022
Condiments	0.022
Total	$0.912
Factory Overhead:	
Depreciation	0.053
Factory Expense	0.138
Interest	0.023
Insurance	0.013
Total	$0.227
Selling Expense:	
Brokerage and Commission	0.038
Sales Allowances and Selling Expense	0.011
Discount allowed	0.019
Total	$0.068
General Expense:	
Administrative and Clerical Salaries (portion)	0.048
Miscellaneous General Expense	0.016
Total	$0.064
Grand Total	$1.271

Present costs differ somewhat from the above, but the relative costs of the various items are typical.

U. S. Standards for Canned Peas.—The U. S. Department of Agriculture, Bureau of Economics, has established four grades of canned peas. These may be briefly summarized as follows.

U. S. Grade A (Fancy) canned peas are prepared from fresh, young, very tender peas of the same type, are uniform in color, and unless

declared to be ungraded for size, are uniform in size. They are surrounded by practically clear liquor; are practically free of skins, broken peas, and other defects; possess the typical, fresh flavor of succulent, immature peas; and score not less than 90 points according to the United States scoring system for canned peas.

The specifications for U. S. Grade B (Extra Standard or Choice) canned peas are similar to Grade A except that the words "practically free from" are replaced by "reasonably free from" and the peas must score 75 to 89 points in quality.

U. S. Grade C peas are reasonably tender, reasonably uniform in color and score from 60 to 74 points in quality.

Off grade (Substandard) canned peas are those that do not meet the requirements for Grade C but must, of course, be clean, wholesome food. Such peas must be suitably labeled.

The scoring system is as follows:

	Points
I. Clearness of liquor	15
II. Absence of defects	15
III. Uniformity of size and color	10
IV. Tenderness and maturity	35
V. Flavor	25
Total	100

Directions are given for arriving at values for each of the qualities listed. In doubtful cases tenderness is determined by measuring the pressure in pounds required to crush the peas in a special apparatus.

Net drained weights are also specified for various sizes of cans. The maximum head space permitted in a No. 2 can is 9.7 sixteenths of an inch. For further details see *SRA* 140, United States Standards for Grades of Canned Peas.

PIMENTOS

Pimentos, large, red, smooth, sweet, bell peppers, are canned extensively in the southern part of California and Georgia. They are successfully grown in many of the Southern States, and it is probable that commercial canning of this vegetable will extend to these states. They are also canned commercially in Spain and the Spanish product competes with the product from California and Georgia.

Pimentos for canning purposes should be large, smooth-skinned (not wrinkled), deep red in color, and sweet in flavor.

Peeling.—The most satisfactory process of peeling consists in roasting the pimentos until the skin may be easily slipped from the flesh and is accomplished by passing the pimentos through a slowly rotating iron cylinder heated by gas flames; or by chain conveyer through a gas-flame-

filled firebrick furnace. The rate of rotation is approximately 12 r.p.m., and the pimentos are heated for about 1 min. They then go through a spray washer which removes most of the peel and from here to the peeling tables where the remaining skins are slipped from them by hand. The cores and stems are removed at the same time by a knife similar in construction to a peach-pitting spoon. The roasting not only removes the peels but softens the flesh of the pimentos so that they may be flattened and packed tightly into cans.

In another peeling process the pimentos are heated in a vat of cottonseed oil at a temperature of about 400°F. for about 3 or 4 min., which accomplishes practically the same result as the roasting process, although it is claimed that roasting imparts a desirable flavor which cannot be obtained by the oil peeling process.

Pimentos may be peeled with boiling lye but lye peeling is not considered so satisfactory as other methods.

Canning and Sterilizing.—The perfect specimens are packed carefully by hand into small cans or jars and usually no liquor is added. In this respect pimentos resemble "solid-pack" tomatoes. In some canneries a small amount of water or dilute brine is added. Because of the solid consistency of the pack, it is necessary to exhaust the cans very thoroughly, preferably 12 to 15 min. at 200 to 212°F. Small cans are processed in boiling water in an agitating cooker for about 30 min. Acidification may be desirable in some cases.

RHUBARB

(Rheum rhaponticum)

Rhubarb more nearly resembles a fruit than a vegetable in composition. On account of its high acidity it attacks tin plate vigorously and perforation of cans is common.

The rhubarb is washed, cut in short lengths and is either packed at once into cans with water, or is cooked a short time in a jelly kettle and packed hot into cans, the latter method being preferable because it gives a better filled can.

The process is about 13 min. at 212°F.

PUMPKIN

(Cucurbita pepo L.)

Canned pumpkin has made pumpkin pie available at all seasons of the year, and pumpkin canning has become an important industry.

Pumpkins for canning should be of the hard, sweet varieties, evenly ripened, and the flesh should be of good texture, golden yellow, but not watery.

Pumpkin is canned late in the fall after the season for tomatoes has closed.

The pumpkins are washed and stemmed, they are cut in pieces by large knives or hatchets or by special roller disks, and the pieces are washed in a revolving circular screen ("squirrel-cage") washer to remove seeds and fiber, or this material is removed by a revolving, blunt, broad cone against which the halved pumpkin is held by hand.

The pieces are then steamed in retorts at 240°F. for 20 min. until the pumpkin is well softened; or it may be steamed in a continuous steam cooker designed for the purpose.

The pulp is separated from the skin and tough fiber by a heavy tomato pulper, and the pulp so obtained is evaporated in open kettles to a heavy density and canned hot as a solid pack. Enamel-lined cans should be used to prevent darkening of the product.

No exhaust is necessary. The process is usually conducted at 250°F. for 90 min. for No. 2½ cans, heat penetration being extremely slow because of the heavy consistency of the pumpkin. Number 10 cans require 110 min. at 250°F. In both cases an initial temperature of 180°F. is assumed. Those who contemplate the canning of pumpkin should consult a canning research laboratory.

A good can of pumpkin should be smooth, evenly screened, free from fiber, and uniformly colored. When opened, the can should be filled to within ½ in. of the top.

SPINACH

(Spinacea oleracea)

The commercial canning of spinach has become an important industry owing to the belief that it is high in vitamins and valuable mineral food elements and on that account a desirable food for children.

Culture and Harvesting.—There are a number of strains of spinach. In California the Prickly Seeded, Amsterdam Prickly Giant, and Prickly Winter varieties are more popular than the Savoy since the leaves are thinner. The Savoy is more commonly used by market gardeners. The Viroflay variety is grown in southern California.

In California the seed is planted in rows about 15 to 20 in. apart in the fall, usually in November. Spinach is fairly resistant to the mild frosts occurring in that state and grows during the winter and early spring without irrigation, as the winter rains supply sufficient moisture.

When the spinach has attained proper size and maturity, *i.e.*, when the blossom stalks have begun to form, the plants are cut a short distance beneath the soil by two blades attached to a sled drawn by a horse. Workmen gather up the spinach, discarding defective heads and weeds.

The harvesting season in California is usually in April. In the eastern states spinach is sown in the spring as soon as weather conditions permit and is harvested in May or June. Spinach requires cool weather and is not a satisfactory summer crop.

The cut heads, in California, are placed in crates, usually of 40 to 60 lb. capacity. These are loaded on trucks and taken at once to the cannery.

It should be canned at once, since if allowed to stand very long, it is apt to rise in temperature, wilt, and deteriorate in quality. If for any reason it cannot be canned within a few hours after cutting, it should be placed in a cool, well-ventilated room and the crates stacked so as to permit free circulation of air.

The U. S. Department of Agriculture has established standards for U. S. No. 1, No. 2, No. 3, and Unclassified fresh spinach for canning, based upon freedom from or presence of yellow leaves, decay, grass, weeds, roots, insects (aphids and worms), mildew, seed stalks, coarse stalks, wood, soil, or other foreign material. Canners sort and grade one or more crates from each load and pay the grower accordingly, deduction being made from the contract price for presence of an excessive amount of unfit material. In the Hayward district of California in 1936 the growers were allowed 30 per cent normal waste.

Trimming and Sorting.—The spinach crates holding 40 to 50 lb. each are placed in an inclined position before women who trim off the roots, some of the stalks if necessary, and remove trash and yellow leaves. Each operator can prepare about 1⅓ crates per hour.

Washing.—Owing to the fact that spinach leaves grow on or near the surface of the soil and are subject to heavy rains, they are apt to carry considerable soil. Insects, *i.e.*, aphids and small worms, are sometimes present in considerable numbers. Hence spinach leaves must be very thoroughly washed. Usually they are first carried through a long tank of water where they are subjected to agitation and sprays. They then pass through a rotary-drum spray washer where they are subjected to heavy sprays of water under 60 to 200 lb. pressure per square inch. These cut most of the soil and insects from the leaves.

The washed spinach should be sorted on a slowly moving belt to remove any defective leaves, weeds, and trash that may have escaped the trimmers.

Blanching.—The blanching of spinach has undergone considerable change since the preparation of the First Edition of this book, in 1920 to 1923. At that time the following statement was made. "The blancher consists of a rotating screen cylinder which carries the spinach through hot water, the temperature of which is varied according to the tenderness of the product. For example, a temperature of 185°F. may be used for small tender leaves, 200°F. for medium and 212°F. for tough leaves."

In September, 1928, a patent was issued on the blanching of vegetables to W. E. Thomas of the Thomas-Body Canning Company of Oakland, Calif. In the patent it is stated that "the maximum allowable temperature for the purpose is approximately 160°F." It is a curious fact that spinach so blanched is after canning more nearly like cooked fresh spinach in color than is that blanched at near the boiling point. The latter is gray to gray-green in color. There is difference of opinion concerning the cause of better green color retention in canned spinach blanched at about 160 to 170°F. The inventor states in his patent application:

> It appears that the changes effected in the chloroplasts by the uniform and relatively slow heating thereof at the temperature specified are such as to render the chlorophyll thereafter less susceptible to the influence of heat for transforming it into phaeophytin. That such is indeed the case is further indicated by the fact that, after a period of not less than four minutes of the treatment at the fixing temperature, the temperature may then be raised without effecting a change in color of the vegetable.

The patent is held by the California Packing Corporation, which has brought suit for infringement against another large company. The California Packing Corporation holds a patent by Lesley and Shumate on the blanching of spinach.

The hot, blanched spinach is again sorted on a moving rubber belt before going by conveyer to the canning tables.

Canning.—The hot spinach is usually packed into cans by weight by women whose hands are protected by rubber gloves. Formerly the leaves were rammed tightly into the cans, but owing to the fact that heat penetration was seriously retarded thereby, the California State Board of Health has established maximum cutout weights based on a moderately filled can. Filling by machine is also in use; it is a logical development as the cans may then be filled very hot.

The maximum drained weights are: for No. 1 tall cans, 8.0 oz.; for No. 2 cans, 14.5 oz.; for No. 2½ cans, 21 oz.; and for No. 10 cans, 70.0 oz.

Brining.—In California the dilute brine is added hot by a nozzle inserted into the contents of the can. Formerly a conical hole was made in the center of the can of spinach by plunging a conical wooden peg into the mass, and brine was filled into this hole, with or without previously injecting live steam into the mass.

Exhausting and Sealing.—Number 10 cans require 10 to 14 min. exhausting. If sealed at too high a temperature, excessive paneling (partial collapse) of No. 10 cans will result after canning and cooling. Number 10 cans are usually sealed at about 150°F. and smaller cans at a somewhat higher temperature.

The exhausted cans are sealed in usual manner. One large canner uses a vacuum sealer for part of his pack. In this case the cans are sealed directly after brining and without exhausting by heat.

Preheating.—In most canneries the sealed cans are passed through boiling water and steam in an agitating cooker to preheat the contents to about 180°F. and to break up matted masses of leaves.

Processing.—Formerly the California State Board of Health required that canned spinach have an initial temperature before processing of at least 180°F., or that the process time be correspondingly lengthened if the initial temperature was below 180°F. At present, however, it is required only that the initial temperature be at least 140°F. The specified processing temperature is 252°F. Since blanched spinach tends to stratify horizontally in No. 10 cans, it is recommended by the National Canners Association that these cans be processed in a horizontal position.

The process times are given in Table 34.

Table 34.—Processing Times for Spinach at 252°F. and an Initial Temperature of at Least 140°F.

Can Size	Time at 252°F. Minutes
8 oz. short	35
No. 1, Picnic	35
No. 300	35
No. 1 Tall	35
No. 303	40
No. 2	45
No. 2½	50
No. 10	60

Yields.—The loss in trimming and sorting is from 30 to 40 per cent and the yield in California is approximately 35 to 43 cases of No. 2½ cans per ton of fresh spinach as delivered at the cannery.

SWEET POTATOES

(Ipomoea batatas)

The potatoes are canned during October, November, December, and January, when the canning plants are not in use for other vegetables, and most of the canning is done in the Southern States.

Varieties.—Two types are used for canning, *viz.*, the yellow or Jersey type, grown in Delaware, New Jersey, Maryland, and Virginia, and the white type, grown farther south. Because of its yellow color the Jersey is preferred for canning. The Jersey is not so sweet as the white varieties but it is of good flavor and cooking quality.

Steaming.—The potatoes are washed and placed in crates in a retort at 240°F. for 9 to 12 min. to soften and loosen the skins. A quick,

high heating is better for the purpose than a longer cook at a lower temperature.

Peeling.—The steamed potatoes are taken at once to the peeling tables where workers with heavy canvas gloves slip the skins from the potatoes. If properly steamed, the skins slip from the potatoes readily. The potatoes do not peel satisfactorily if they have been allowed to stand so long after digging that they have become shriveled.

Sweet potatoes are also peeled by use of the lye peach-peeling machines described elsewhere but a stronger lye solution and longer lye treatment are required than for peaches. Revolving brushes are used in addition to water sprays to remove the lye-softened skins. Hand trimming is usually necessary with lye-peeled potatoes.

Abrading machines, such as those used for carrots, can be used for sweet potatoes, although the waste in peeling is high and considerable hand trimming is required.

Lye-peeled potatoes or those peeled by machines are steamed to soften them before packing.

Packing and Sterilizing.—The hot peeled potatoes are tightly packed at once into sanitary cans with the addition usually of a small amount of water. The cans are heaped full and the potatoes are pressed in tightly.

A long exhaust is desirable, because the solid-packed potatoes conduct heat very slowly. Bitting recommends 18 min. at 185 to 200°F. The National Canners' Association recommends the following 240°F. processes if the initial temperature is 150°F.: No. 1 Picnic size can, 65 min.; No. 2 can, 95 min.; and No. 2½ can, 110 min. If the initial temperature is 180°F., the times at 240°F. are 60, 85, 95, and 100 min., respectively.

Darkening and Springers.—Overfilled cans become springers and, although wholesome, are not purchased because of their bulged appearance.

Potatoes in slack-filled or insufficiently exhausted cans may blacken, a condition caused by solution of iron, its oxidation to the ferric condition, and its combination with tannin of the potato.

TOMATOES

(Lycopersicum esculentum)

According to Bitting, the first record of the canning of tomatoes is of that done by Harrison W. Christy in 1847 at Jamesburg, N. J. Tomatoes are now used in enormous quantities in the fresh state, as canned tomatoes and in the form of juice, purée, paste, and various relishes, such as catsup, chili sauce, etc.

Importance of the Industry.—Tomatoes at one time headed the list of canned fruits and vegetables in quantity, although in recent years they have occasionally been exceeded by corn or peas.

Worsham has studied the data for production and consumption of tomatoes and has arrived at the conclusion that the consumption of canned tomatoes is decreasing. He attributes this decrease to the importation of tomatoes other than juice during the winter and spring from Mexico and the southern United States and to the increase of home gardening with consequent increase in the home canning of tomatoes. It is possible also that the general sale of low-grade canned tomatoes a few years ago did much to destroy the confidence of the public in the product.

Table 35 gives the comparative production of tomatoes, peas, and corn since 1907.

TABLE 35.—COMPARATIVE PRODUCTION IN THE UNITED STATES OF CANNED TOMATOES, PEAS AND CORN

(Tomatoes in cases of 24 No. 3 cans each and peas and corn in cases of 24 No. 2 cans each)

Year	Tomatoes, cases	Peas, cases	Corn, cases
1907	12,918,206	5,885,064	665,044
1909	10,984,200	5,028,000	5,787,000
1911	9,749,000	4,532,000	14,337,000
1913	14,206,000	8,770,000	7,283,000
1915	8,469,000	9,272,000	10,124,000
1917	15,076,000	9,829,153	10,803,015
1919	10,809,000	8,685,000	13,550,000
1920	11,368,000	12,317,000	15,040,000
1935	15,381,000	24,698,000	21,471,000

It will be noted that the packs of all three vegetables have been subject to large fluctuations from year to year.

Varieties of Tomatoes for Canning.—Tomatoes for canning should be moderately large, smooth, so that peeling can be easily accomplished, evenly ripened to the stems, of a clear red color and possessing a large proportion of solid meat of good flavor. Those of irregular shape and wrinkled skins are difficult to peel and the loss in preparation is excessive. Some varieties possess large seed cavities and on this account soften badly in the can, giving an unattractive appearance and a slack-filled can. Soft, watery varieties are objectionable for similar reasons. Yellow and purple tomatoes are not desirable; a deep, uniform red color is the ideal. Lack of uniformity in ripening excludes some varieties for canning.

Not only must the tomato possess desirable canning qualities but it also must yield well to be grown profitably. Early ripening, therefore, is desirable, since yield is largely influenced by the length of the picking season.

Seedsmen and others have developed a number of excellent strains of tomatoes for canning purposes. Of these, the Stone is perhaps the best known and most widely grown. It is a medium large, smooth-skinned, bright-red tomato with a large proportion of solid meat. It is a regular bearer but ripens over a comparatively short season.

The San Jose Canner is popular in California. It is a large tomato of rather irregular outline and is somewhat flattened vertically. It is a heavy bearer and ripens over a long period, but many canners believe its form and color could be improved by breeding experiments. In southern California the Norton, a Stone selection, is grown because of its resistance to fusarium wilt. The Santa Clara Canner and Diener are grown extensively in northern California. They resemble the San Jose Canner.

The Matchless is said to be grown extensively in Delaware and Maryland. It is oblate in form in vertical section and circular in horizontal section. It is of large size and relatively free from corrugations, and the flesh is firm and of reddish-pink color. The pulp around the seed cavity is yellowish red. It ripens rather late and is claimed to be a more irregular bearer than the Stone.

The Paragon is a large, flattened, solid, bright-red tomato of good canning quality and early ripening and has a tendency to develop prominent ribs.

The Landreth is an excellent canning variety. Other canning varieties grown commercially are the Coreless, Perfection, Greater Baltimore, Favorite, Red Rock, and Success. The Perfection is an early variety and the Coreless one of the best late-ripening varieties.

Propagation.—Canners have found by experience that it is desirable for the canners themselves to propagate the young plants in hotbeds and cold frames in order that the proper varieties shall be grown. When the purchase or propagation of young plants is left to the choice of the growers, the cannery will usually receive several varieties, of varying canning quality.

Picking and Transportation.—The picking season varies with the locality. In California, picking for canning purposes usually begins about Aug. 5 to 10 and continues until about Dec. 1. In Maryland the season is approximately from Aug. 20 to Oct. 20; in Indiana, Aug. 1 to Nov. 1; and in some of the Southern States from about July 15 to about Oct. 15.

Tomatoes for canning must be prime ripe, without green areas around the stem end and not overripe. In order to secure tomatoes in this condition the fruit must be gathered every day or every other day; otherwise a great deal of it will become overripe.

Shallow boxes are to be preferred to deep baskets or deep boxes. The tomatoes in the bottom of a deep container are subjected to considerable pressure and may become crushed or cracked during transit.

Boxes should be provided with cleats across the ends to prevent crushing, when the boxes are piled one above the other, and to provide ventilation between the boxes.

Tomatoes should not be allowed to stand in the fields in the sun after picking, because this will cause overripening and development of microorganisms, but should be transported to the cannery as promptly as possible and without undue bruising or crushing in transit.

Sampling at Factory.—At the factory, immediately on delivery, a representative sample should be taken by the canner, and the proportions of prime fruit, rotten fruit, and green fruit determined. This can be done by dumping one or two boxes, taken at random, into a tank of water and sorting the sample carefully. The grower can then be paid for the fruit which is suitable for canning purposes and "docked" for rotten and green fruit. By no other means is it possible to maintain a delivery of desirable fruit and reduce to a minimum the delivery of unfit material. Particularly is this true near the end of the season when early fall rains have damaged a large proportion of the crop. The United States Department of Agriculture has established specifications for U. S. No. 1, U. S. No. 2, and Cull grades upon which canners may purchase tomatoes. This has been done to a limited extent but is not general practice. If the tomatoes are to be used for products such as catsup, etc., they are carefully inspected by the canner and usually, in California, by the State Board of Health inspectors, for rot and insects.

Storage at Cannery.—Tomatoes deteriorate rapidly after delivery and should be canned as promptly as possible.

Washing Empty Boxes.—Under the best conditions picking boxes become contaminated with mold, yeast, and bacteria which develop in tomato juice or pieces of pulp on the bottoms and sides of the boxes. Therefore, boxes should be thoroughly washed and steamed at the cannery before return to the grower.

Washing.—Although the washing of tomatoes is not so important in canning as in the manufacture of tomato pulp, nevertheless it is often desirable to wash the fruit before scalding. This is especially true after rains and where the fruit may have been grown in close proximity to wet clay soil.

Washers.—The most efficient washer for tomatoes consists of an inclined, perforated metal-drum screen fitted on the inside with longitudinal corrugations or a spiral conveyer. The tomatoes rub against each other as they traverse the cylinder and are subjected to heavy sprays of water. The rubbing softens the dirt, and the sprays remove it (see Fig. 10).

Another common type of washer is that known as the apron washer. The tomatoes are carried on a door-matting conveying belt beneath

sprays of water. Sprays may also be played against the tomatoes from below the belt with good effect. This washer is less liable to break or bruise tomatoes for canning. Simply allowing the tomatoes to pass through a tank of water adjacent to the scalding machine usually does not remove the dirt effectively.

Testing.—The effectiveness of the washing process can be determined by allowing some of the tomatoes to dry in the air, after washing. If they have not been thoroughly washed, a film of dirt will be evident on the dried fruit. The water used in washing must be renewed frequently, otherwise it may add more dirt to the tomatoes than it removes.

Sorting and Trimming.—In the canning of tomatoes in the majority of plants, the peelers do most of the sorting. However, sorting can be

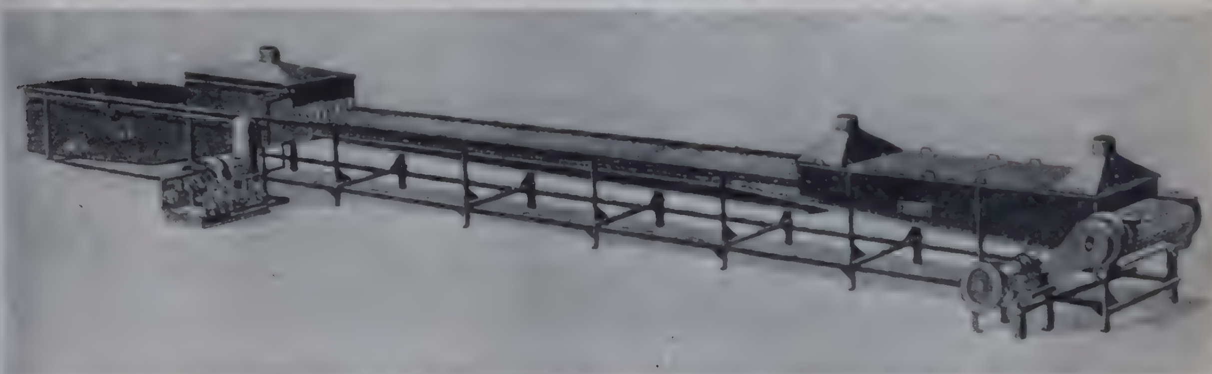

FIG. 45.—Tomato scalder and sorting belt. (*Courtesy Food Machinery Corporation.*)

more efficiently and satisfactorily done by a few sorters than by a number of peelers. Peelers are apt to be more careless in the sorting of the tomatoes and are particularly liable to throw rotten fruit and other unfit material into the bucket containing peels and cores for pulping. If the washed tomatoes are very carefully sorted in such manner that only the large perfect fruit goes to the scalder, the rotten fruit to the dump, and the small and misshapen fruit to the pulping line, sorting will be a very profitable investment. Only the best tomatoes should be used for canning. Small, badly wrinkled, unevenly ripened, and overripened fruits should be used only for pulp.

Tomatoes that carry a small amount of rot or green areas may often be trimmed and used for canning as standard grade.

In sorting and trimming, the tomatoes are carried on a broad belt or woven-metal conveyer before the sorters. For effective sorting the belt should move at a rate not to exceed 25 ft. per minute, and according to B. J. Howard, it should be equipped with turning devices at regular intervals, as experience has shown that the sorters otherwise allow many of the tomatoes to pass without turning, thus permitting unfit fruit to pass to the peeling tables.

Scalding.—Tomatoes are scalded sufficiently to loosen the skin but not so long that the pulp and flesh become softened or the tomatoes

thoroughly heated. The scalding is accomplished by conveying the tomatoes through boiling water or live steam. Very often the same conveyer that carries the tomatoes before the sorters carries them through the steam scalder, which in this instance is merely an enclosed sheet metal box filled with sprays of live steam.

The tomatoes are exposed to the live steam or boiling water from ¼ to 1 min., depending upon their condition. As they emerge from the scalder they are subjected to sprays of cold water or are immersed in cold water to check further cooking and to crack the skins (see Fig. 45).

Hand Peeling.—The scalded tomatoes are delivered by conveyer or in dishpans or buckets carried on belts to the peeling tables where they are peeled by hand. The pans should not be deep, in order to avoid continued cooking or crushing. Prompt peeling is essential in order to avoid incipient spoilage.

The tomato is peeled by first pulling the skin back from the blossom end with the blade of a short coring and peeling knife. The operation is completed by removing the core with the point of the knife, which is directed toward the center of the tomato to avoid opening the seed cavity. A knife commonly used for this operation is spoon-shaped. Green and otherwise undesirable spots are removed by the peelers.

The peeled tomatoes are usually placed in broad pans or buckets and are conveyed by a belt to the canning tables, and the sound cores and peels are usually placed in buckets or on a belt and sent to the pulping machines for the manufacture of low-grade purse, which is used for addition to standard-pack tomatoes or for low-grade catsup, etc. Unfit trimmings and rotten material are discarded. Great care must be taken at the peeling tables so that rotten fruit does not find its way into the pulp stock.

Pans, buckets, conveyers, floors, and all machinery used in the handling and treating of tomatoes should be frequently washed. A clean plant encourages cleanliness and care on the part of the employees and will improve the quality of the pack.

The loss in peeling varies from about 20 to about 50 per cent, but much of this material is often utilized for the production of purée. Peelers vary greatly in the per cent loss in peeling. Experienced, careful peelers may waste only 20 or 25 per cent, whereas a careless peeler may waste 40 to 50 per cent.

Solid Pack.—The whole, firm, evenly colored tomatoes are packed carefully by hand into cans without the addition of juice or purée and are known as "solid-pack" tomatoes. There is danger of overfilling, a condition which will result in the development of flippers or springers and cause the product to be unsalable, although perfectly wholesome.

Some canners add to each can of the highest grade of tomatoes a level teaspoonful of an equal mixture of salt and sugar in order to improve the flavor.

Standard Pack.—Standard-pack tomatoes consist of the small tomatoes, those of imperfect color, soft tomatoes, and trimmed tomatoes. Often purée from trimmings and cores is added to fill the spaces between the pieces and to cheapen the product, by utilizing otherwise waste material. The cans are often filled by machines which add the product by volume rather than by weight. The standard tomatoes are just as nutritious and wholesome as the solid pack and are cheaper. Therefore they have a legitimate place, if carefully prepared and not mixed with too much purée.

Addition of Water.—The addition of water to tomatoes is never necessary or desirable and constitutes an adulteration. Bitting has studied the effect on the composition of the canned product of the addition of various amounts of water at the time of canning as set forth in Table 36.

TABLE 36.—EFFECT OF ADDITION OF WATER ON CUTOUT WEIGHTS AND COMPOSITION OF CANNED TOMATOES
(*After Bitting*)

Water added, ounces per No. 3 can	Drained weight of tomatoes, ounces	Weight of liquid, ounces	Specific gravity of liquid
0	23.1	11.2	1.023
0	21.3	13.0	1.022
2	19.5	14.9	1.021
4	18.1	16.5	1.020
6	17.2	17.5	1.018
8	15.1	19.3	1.018
10	14.2	19.4	1.017
12	13.6	19.7	1.014
14	10.8	21.5	1.013
16	9.8	22.3	1.011

Tomatoes are sometimes packed whole in a single layer in flat shallow No. 3 or 10 cans for use in salads and are given a short sterilization in order to avoid softening.

Exhausting.—Tomatoes should be thoroughly exhausted at a moderate temperature because solid-packed tomatoes heat very slowly. The center of the can should reach at least 130°F., if possible 150°F., and the length of the exhaust should be adjusted to accomplish this end. Too short an exhaust may result in springers or flippers through overfilling.

Processing.—The agitating continuous cooker for tomatoes, operating at 212°F., has largely superseded the retort and the open cooker formerly used. Most canners of tomatoes are also canners of fruits and find it convenient and economical to utilize as far as possible the same equipment for both products.

In an open nonagitating cooker, tomatoes are sterilized for 30 to 55 min. at 212°F. in Nos. 2½ and 3 cans. The length of time varies according to the consistency of the pack. Solid-pack tomatoes conduct heat more slowly than standard-pack goods and hence require a longer processing. In the agitating continuous sterilizer the time has been reduced to as low as 15 min. However, considerable spoilage may occur unless the centers of the contents of the cans attain 190°F. or higher. For a No. 2½ can this will require about 25 min. in an agitating cooker. Temperatures are taken regularly during the day by plunging an armored, sharp-pointed thermometer to the centers of several cans taken directly from the outlet of the cooker. During the 1937 season in California the above process failed to prevent spoilage in all cases, owing to high pH of the tomatoes and presence of a heat-resistant bacillus.

Tomatoes should be cooled completely and quickly after sterilizing in order to avoid "stack burning," *i.e.*, browning of the color and loss in flavor.

Cutout Weights.—The total net contents of a No. 2½ can should weigh at least 28 oz., of a No. 3 can 33 oz., and a No. 10 can at least 103 oz., although no minimum standards for net-drained weights have been established by the government. It, however, has ruled that head space must not exceed 10 per cent of the total inside height of the can. Tomatoes vary greatly in consistency and in the weight of the drained material on the cutout test, according to variety, season, location, and the temperature and time of sterilization.

Sanitation.—Buckets and pans should be washed each time they are used, and floors should be washed at least twice daily. Machinery should be washed frequently, which in some cases means partial dismantling and hand scrubbing of working parts.

If tomatoes are to arrive at the plant in sound condition, lug boxes must be frequently washed.

In other words cleanliness and orderliness in and about a cannery are essential to satisfactory operation.

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(See also list at end of Chap. XI)

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CHAPTER XIV

SPOILING OF CANNED FOODS

All canned foods, after sterilization, are subject to deterioration during storage. In many cases the changes that occur do not render the food unfit for consumption; nevertheless the appearance of the container or of the product may become so unattractive that it becomes unsalable. Two general types of deterioration are recognized: (1) spoiling by microorganisms and (2) changes brought about by chemical or physical agencies. Microbiological spoiling of canned foods is the more important.

DEFINITIONS

Spoiled cans of food exhibit characteristic differences in appearance, taste, and odor from normal cans. The most common designations in use for the different types of spoiled or abnormal cans of food are given below.

Swell.—A swelled can is one whose ends are tightly bulged from the formation of gas within the can by microorganisms and the ends of which remain convex and spring back to this position if pressed inward. Swelled cans of food are usually so badly decomposed as to be unfit for consumption. They may be poisonous because of the presence of *Bacillus botulinus* (*Clostridium botulinum*).

Hydrogen Swell.—A hydrogen swell is caused by the formation in the can of hydrogen gas as a result of corrosion of the tin plate. The contents are usually sterile and often fit for food.

Springer.—A springer may be merely a mild swell or a mild hydrogen swell; it may be caused by overfilling the can or by insufficient exhausting. Swells always pass through the springer stage. The ends, or at least one end, of a springer can be pressed in with the hand and will remain convex for a time. Springers, if caused by overfilling, underexhausting, or corrosion, can be used for food.

Flipper.—A flipper is a can under very mild positive pressure. It may be of normal appearance, but the end, if struck sharply against the top of a table or other solid object, will become convex. It may represent the initial stage of a swell or hydrogen swell or, more frequently, be due to overfilling or underexhausting.

Flat Sour.—A flat sour is a can of food which has undergone spoilage by microorganisms without gas formation and is normal in outward

appearance. The product usually possesses a sour taste and frequently a sour odor. Vegetables frequently undergo this type of decomposition, which is usually a nonpoisonous change. Occasionally this condition is caused by bacterial spoiling before canning.

Leakers.—Cans may leak because of (1) faulty seaming of the factory end of the can, (2) faulty seaming of the cannery end of the can, (3) faulty lock seaming, (4) pinholing by corrosion from the inside of the can or rusting of the outside of the can, and (5) bursting of the can by excessive gas pressure developed in the can by decomposition, by microorganisms, or by formation of hydrogen gas through corrosion.

DISCOLORATION

While not so serious a cause of loss as spoiling by microorganisms, discoloration is nevertheless a serious problem for the canners of vegetables and apples.

Corn.—There frequently develops in canned corn a dark-gray color throughout the product, or an inky-black, scale-like deposit on the interior of the can. The problem has been investigated by Bigelow (1915) and his associates of the National Canners' Research Laboratory. Their conclusions are that the uniform darkening of the entire contents of the can is due to the formation of copper sulfide and that the black deposit on the tin plate and small pieces of sulfide in the product is iron sulfide.

Copper Sulfide.—It was found in their experiments that as little as one part of copper per million parts of corn was sufficient to produce appreciable darkening. The trouble is most likely to occur during the first part of the canning season or after the plant has been shut down for a few days. The cause is the formation of a thin film of copper oxide or copper salts on the surface of copper kettles or other copper or brass equipment with which the corn comes in contact at some stage in the canning process. The copper oxide, or salt, dissolves and reacts with the hydrogen sulfide formed from the decomposition of the protein of the corn during sterilization.

Iron Sulfide.—The formation of the black scale or black pieces of iron sulfide is a much more serious problem than the darkening caused by copper salts. The sulfide is intensely black and is very finely divided; hence a relatively large amount of corn may be colored by a very small amount of this compound. It is not injurious to health and only the appearance of the corn is affected.

Bigelow (1916) states that there are two distinct steps in the formation of the deposit: first, a corrosion of the plate during processing and later a combination of the dissolved iron with the hydrogen sulfide formed during sterilization. He also states that the deposit does not normally form in direct contact with the corn because of the inhibiting effect of the acid

of the corn and that the principal formation of the black deposit occurs on the plate above the level of the corn.

Fitzgerald, Bohart, and Kohman made an exhaustive study of the problem and came to the following conclusions: (1) No variety of corn is free from discoloration. (2) There is no procedure known by which the canner may control his conditions or methods in order to prevent the formation of iron sulfide discoloration in canned corn. (3) Iron sulfide discoloration occurs with both bessemer and open-hearth steel. (4) The use of heavy tin coating does not prevent the discoloration. (5) Discoloration occurs less with acid flux cans than with rosin flux cans, but empty acid flux cans are liable to rust in storage. (6) Discoloration becomes more pronounced as the maturity of the corn increases. (7) Discoloration is less objectionable when the cans are stored on the side; (8) The black discoloration can be more readily dispersed by shaking when the consistency is not too heavy. (9) The smaller amount of discoloration noted in former years in solder top (hole and cap) cans was undoubtedly largely due to the fact that the cans were made with acid flux and that comparatively large quantities of acid flux were introduced into the can during the closing operation. (10) Changing the profile of the can to cause less strain on the steel or less disturbance of the coating does not prevent blackening. (11) Discoloration is no worse in cans made of black plate with no tin coating than in those carrying a heavy tin coating. (12) Tight seams are necessary to avoid air and rust discoloration which accelerate formation of the black sulfide. (13) No practicable method was found at that time for preventing the formation of black by mixing any substance with the corn. Many different organic and inorganic substances were tested in this connection. (14) Zinc salts greatly reduce the formation of black, but when mixed with the corn, the amount necessary is so great as to be impracticable. When dissolved in water and allowed to dry on the surface of the can, much less is required. The salts may be replaced by zinc plating the lid of the can, which gave promise of yielding practical results, very much less zinc being required apparently in this form than in any other. (15) Discoloration owing to bacterial action may follow insufficient cooling, but this blackening occurs throughout the contents of the can. (16) Corn should be filled into the can hot, at a temperature of at least 190°F. and the cans should also be filled as completely as possible. Both of these steps are taken to reduce the amount of air in the corn and in the head space. (17) All corn should be well shaken before shipment to disperse the black deposit, and heating before shaking is desirable to give a more liquid consistency. (18) All wholesalers should be warned that blackening may occur in storage in their warehouses and that cans should be placed on their sides instead of on end.

Such was the status of the knowledge of this very costly form of deterioration in 1922. Bohart of the National Canners' Association and research chemists of the American Can Company continued the research begun by Bigelow and associates, concentrating their attention on the role of zinc compounds in preventing formation of iron sulfide. In 1924 Bohart published upon the preparation and use of a can enamel containing a small amount of zinc oxide. At present practically all canned corn is packed in containers lined with this enamel, which is commonly known in the industry as "C-enamel" or "Corn-enamel." A public service patent was granted upon this process. Any hydrogen sulfide formed during processing reacts with the zinc oxide in the enamel to give white zinc sulfide, which for the most part remains in the enamel without materially changing its appearance. It differs but little from the zinc oxide as both are white in color and finely divided. At the low acidity of corn the zinc sulfide is stable; hence zinc does not go into solution to an appreciable extent. The enamel possesses a characteristic "dusty," or gray appearance. Its use has solved the corn black problem in very effective manner. The industry is greatly indebted to Bohart and those who worked upon this problem with him.

C-enamel also is used for lining cans in which are canned certain other foods prone to form hydrogen sulfide during processing.

Paper gaskets if not tightly rolled in double seaming may "breathe," *i.e.*, admit air slowly. This condition results in increasing the amount of deposit. The oxygen thus admitted first causes rusting and the iron oxide thus formed is later converted to the sulfide. Fitzgerald found that corn heated for 6 hr. by intermittent sterilization (2 hr. on each of three successive days) gave a product equal in flavor to freshly cooked corn and with no black deposit. Evidently the hydrogen sulfide is formed at higher temperatures than 212°F. The corn in the above experiment, however, finally underwent bacterial decomposition because 212°F. did not sterilize.

Blackening of Peas.—Peas sometimes develop a flaky black deposit similar in appearance to, and probably identical in composition with, the iron sulfide deposit in cans of corn.

It has been found that allowing the peas to undergo heating or sweating before canning increases the tendency to the formation of the black deposit. It is probable that the incipient decomposition which occurs under such conditions results in the formation of hydrogen sulfide from the breaking down of protein. It is therefore to be recommended that peas be canned as promptly as possible after harvesting.

Thorough washing and blanching before canning, it is believed, also reduce the tendency for formation of the black deposit. Use of cans lined with C-enamel prevents formation of the black deposit. Peas some-

times dissolve copper from unclean equipment with a subsequent development of a black deposit of copper sulfide.

Black Deposit in Canned Fruits.—Canneries in California during the 1921 season suffered some loss through the use of a grade of cane sugar known as "plantation granulated," in the manufacture of which sulfur dioxide is used. It is usually very light yellow or nearly white in color, is cheaper than refined sugar, and if free from sulfur dioxide can be used satisfactorily for peaches, other dark fruits, and berries. The experience of the 1921 season, however, proved that it sometimes contains sufficient sulfur dioxide to cause serious blackening of the tin plate and in some cases the production of a hydrogen sulfide odor. The sulfurous acid reacts upon the plate and is reduced to hydrogen sulfide, which in turn reacts with the dissolved metals to produce a black deposit of metallic sulfide.

Sulfur from new sorting belts has occasionally caused a black deposit in canned fruits by reduction in the can to hydrogen sulfide and subsequent combination with iron to give iron sulfide.

Pink Pears and Peaches.—If canned peaches and pears are not thoroughly cooled after sterilization they will frequently become pink in color. It has also been claimed, but not proved experimentally, that overheating of the fresh fruit before canning, during shipment or storage, will result in the formation of a pink color after canning and that pears grown in very hot localities frequently develop a pink color after canning.

Pumpkin.—Canned pumpkin frequently "detins" the container and causes the formation of a heavy black deposit on the exposed steel surface. According to Huenick the corrosion is due to the amino compounds of the pumpkin; however, the use of heavily lacquered cans prevents this trouble.

Apples.—Apples will cause vigorous corrosion of tin plate if not thoroughly exhausted or otherwise treated before canning to expel air from the can and from the fruit tissues. The dissolved iron may react with the tannin of the fruit to produce a black color.

Browning of apples before canning sometimes occurs. Placing the peeled and cut fruit in dilute brine and thorough blanching before canning will eliminate this type of discoloration.

Sweet Potatoes.—According to Kohman the darkening of sweet potatoes is caused by a combination of the tannin of the potatoes with ferric iron compounds dissolved from the plate. Slack filling of the cans and the entrance of air through leaks permit corrosion and subsequent darkening of the potatoes to take place.

CORROSION AND PERFORATION OF TIN PLATE

A large quantity of canned food is lost annually because of corrosion and perforation of the tin plate, the greatest loss occurring with acid

fruits, such as apples, plums, and berries, although perforation may also occur with less acid products, such as pumpkin.

Relation of Oxygen to Corrosion.—H. A. Baker, one of the first to point out the relation between corrosion of tin cans and oxygen supply, found that the oxygen rapidly decreased in cans after sealing and sterilizing. His investigations indicated that the oxygen combines with the metal of the container, with the food, or with the nascent hydrogen formed by action of acid on the metal. He recommended that oxygen be excluded from the can as completely as possible by thorough exhausting and proper filling.

A number of years ago a cooperative series of investigations was made by representatives of the National Canners' Association, the can manufacturers, and the steel-plate manufacturers. Investigations have also been made by various laboratories in America and in Europe. As a result of this research and of that upon the general problem of corrosion of metals, we now have a much better understanding than formerly existed of the corrosion of tin containers by food products. The following section presents briefly several of the modern theories of metal corrosion.

General Electrolytic Theory of Corrosion.—A brief discussion of the general electrolytic theory of corrosion of metals may serve as a suitable introduction to the corrosion of tin containers by canned foods.

When a piece of metallic zinc is placed in a solution of copper sulfate, the zinc dissolves and copper is deposited on the zinc, the copper being displaced by the more electropositive zinc. In modern chemical terminology, each atom of zinc loses two electrons to a copper ion; although in this simple case no electric current is generated.

If, however, copper sulfate solution is placed in one container and zinc sulfate in another; the two containers are joined by a U tube filled with a salt solution, such as potassium sulfate; a rod of zinc is placed in the zinc sulfate solution and one of copper in the copper sulfate solution; and the two metals are joined by copper wire, a current will be generated. It can be demonstrated readily and measured by a galvanometer. Zinc goes into solution, forming positively charged zinc ions and copper deposits on the copper electrode. Electrons given up by the zinc atoms flow through the wire and neutralize the positive charges on the copper ions, which then deposit as the metal. The salt solution in the U tube acts as an electrolytic conductor between the containers of copper sulfate and zinc sulfate solutions.

If a plate of zinc and one of copper are immersed in dilute sulfuric acid and joined externally by a wire, the zinc dissolves; electrons liberated by the zinc atoms travel through the wire as electric current to the copper electrode, where hydrogen gas (H_2) is formed. In this case the zinc replaces the hydrogen ions of the dissociated, dilute sulfuric acid. They

"plate out" upon the copper and, when a certain voltage is reached, are liberated as H_2. In this case the hydrogen is behaving as a metal. The zinc electrode becomes negatively and the copper electrode positively charged.

In these cases there is electrolytic corrosion of the zinc electrodes. In the electrolytic corrosion of metals it is not necessary that two different metals be involved. It is possible for two different areas of the same metal to form an electrolytic cell if one area is under greater strain than the other or if impurities be present.

Primary and Secondary Factors.—The factors affecting the corrosion of metals may be divided into "primary" and "secondary" factors.

First of the primary factors is the normal potential of the metal, *i.e.*, the electromotive force (e.m.f.) needed to prevent it dissolving against a normal solution of its ions; or it is the force tending to drive it into solution under these conditions. Sodium has a very high normal potential and tin a low normal potential. The normal potential of hydrogen is placed at 0; the more electropositive metals, such as sodium, calcium, iron, etc., are above it in the electromotive series of the metals and the more "noble" metals, such as copper, silver, gold, platinum, and others, are below it in this series. A metal high in this series will displace one lower in the series from solution.

The second primary factor is concentration of the ions of the metal in solution; the higher their concentration the less is the tendency for the metal to go into solution, *i.e.*, to corrode.

The condition in respect to hydrogen overvoltage influences corrosion. Theoretically, hydrogen has a normal potential of 0 and should, therefore, be liberated as gas when it is displaced from solution by a metal. Actually, however, often a potential must be applied to the electrode to displace the hydrogen from the surface, this extra e.m.f. being termed overvoltage. Hydrogen under these conditions protects the metal and retards corrosion.

Hydrogen-ion concentration is another important primary factor. Thus, the more acid the solution the more rapid should the corrosion be, if the hydrogen is removed as fast as it is deposited.

Pitting and consequent development of local cell action may be another primary factor.

There are relatively many secondary factors. Temperature is one of the most important of these. In the open, high temperatures may expel oxygen from the solution and thus retard corrosion; or if the solution is in hermetically sealed cans, high temperatures will greatly hasten corrosion.

Agitation hastens corrosion by continually removing the thin film of dissolved metal and bringing fresh solution in contact with the metal.

Depolarizers are extremely important; in canned foods they are substances that remove hydrogen from the metal surface and thereby make possible continued corrosion. Oxygen is such a depolarizer; it acts by converting the nascent hydrogen into water. Another is anthocyanin, a fruit pigment which is reduced by the nascent hydrogen.

Passivity, cessation of corrosion because of formation of a protective film, as of oxide on aluminum, may develop and stop corrosion.

Accelerators, such as sulfur in canned foods, may greatly hasten corrosion. Traces of this element enormously increase the rate of hydrogen formation in canned fruits.

Inhibitors of corrosion are known. There is said to be one such in beet sugar that retards the corrosion of tin plate.

The viscosity of the medium may in some cases affect the rate of corrosion; the more viscous the solution the slower is the corrosion.

Purity of the metal is of great importance, since impurities may make possible local electrolytic cell action, thereby greatly increasing corrosion and pitting.

Corrosion is seldom uniform over the entire exposed surface of the metal owing to surface variations in the composition or physical condition of the metal, local cell action, etc.

Hydrogen Overvoltage and Polarization.—If an iron electrode is placed in a dilute acid solution, iron dissolves to give ferrous ions and displaces an equivalent amount of hydrogen ions, which give up their positive charges and deposit on the iron surface. The coating of hydrogen behaves as a metal and protects the iron against corrosion by opposing the deposition of additional hydrogen. If the iron is connected by an outside circuit to an electrode of another metal lower than it in the e.m.f. series, such as tin, then the iron for a time still displaces hydrogen ions and forms positively charged ferrous ions; and hydrogen is deposited on the tin. Unless the hydrogen is removed from the tin by imposition of an external voltage or by combination with oxygen or other depolarizer, the deposited hydrogen will exert an e.m.f. opposing further deposition of hydrogen on the tin and thus further solution of iron. Eventually the reaction will cease. In other words the tin electrode becomes polarized. The extra voltage required to force the atomic hydrogen into the molecular, gaseous form H_2 is the hydrogen overvoltage. In the iron-tin couple or cell, H deposited on the tin may exert such a large back e.m.f. that the direction of flow of the electric current is reversed. In other words tin will dissolve, and the iron becomes more "noble" than the tin.

Theories of Can Corrosion.—As previously stated, when iron and tin electrodes are placed in a dilute organic acid solution, at first iron goes into solution and hydrogen plates out on the tin. In a short time sufficient hydrogen accumulates on the tin to exert a counter e.m.f. sufficient to

prevent further dissolving of the iron. As iron has a lower hydrogen overvoltage (a lower e.m.f. being required to evolve hydrogen from its surface) than tin, there is then left only the iron surface for evolution of the hydrogen. Hence, tin then dissolves and hydrogen is liberated from the iron.

During the period when iron is dissolving, iron is anodic, and the tin is cathodic; electrons or "negative" electricity flow from the iron electrode to the tin. During the second phase while tin is dissolving and hydrogen is being liberated from the iron electrode, the current flows in the opposite direction to that of the first period. This reversal of the current was observed by Kohman and Sanborn.

Lueck and Blair attribute this reversal of current to the higher hydrogen overvoltage of tin compared to that of iron, which results in the condition outlined above. This is essentially the Lueck and Blair theory.

Kohman and Sanborn do not entirely agree with the Lueck and Blair explanation of the reversal of potential and give considerable weight to the inhibiting effect of tin salts in solution, in respect to corrosion of the iron. They also call attention to the precipitation of tin by proteins and other food compounds, which in that manner remove tin from solution and thus permit more tin to dissolve. They showed also that, if oxygen is present to act as a depolarizing agent on the tin, iron continues to dissolve in canned apples, and the can becomes perforated because small areas of the exposed iron of the tin plate are corroded through. Kohman showed that the addition to canned apples of the anthocyanin color present in the skins of apples, or the addition of logwood or quercitrin, greatly hastened the corrosive action of this fruit on tin plate.

Culpepper and Caldwell extended Kohman's work to other fruits and their pigments. They concluded that anthocyanin pigments not only act as tin acceptors, *i.e.*, precipitate tin from solution, but also act as hydrogen acceptors, removing hydrogen as rapidly as it is deposited on the metal surface. On this account corrosion of the tin continues. Eventually much iron is exposed; local cell action ensues; iron becomes anodic and dissolves with evolution of hydrogen or perforation of the tin plate.

The following summary may be useful. On the tin plate there are exposed, because of imperfections in the tin coating, very small areas of iron of the base plate. There is also a much larger area of exposed tin than of iron. The two exposed metals are connected by the metal walls of the can and are exposed to a solution of electrolytes, principally a solution of fruit acids. Hydrogen ions from the fruit acids are in solution. There is at first also some oxygen in solution. At first tin goes into solution and hydrogen ions give up their positive charges and deposit on the iron as atomic hydrogen. Oxygen removes the atomic hydrogen to form water and detinning is thereby accelerated. Some tin is precipitated by such

substances as pigments and proteins of the food product. Eventually considerable iron is exposed. It then dissolves with evolution of H_2. Perforation or hydrogen swelling may then ensue. Depolarizers such as oxygen and anthocyanin pigments favor corrosion.

Morris and Bryan make the following very important statements. In the earlier stages of corrosion the high hydrogen overvoltage of tin provides a very great protection against corrosion of the iron. Tin alone in the absence of oxygen is not attacked by fruit acids, but in the presence of iron it is attacked by these acids at a rate depending on the relative areas of the two metals. At low acidity, *i.e.*, pH 4 or 5, attack on the tin plate is more rapid than at higher acidity. The evolution of hydrogen takes place at the iron surface during dissolving of the tin; probably much of the H_2 of hydrogen swells, in cases where severe detinning has occurred, results from this phenomenon. Any increase in the surface of iron exposed by detinning leads to increased corrosion of both metals. In lacquered cans, owing to the small areas of tin plate exposed, detinning is extremely rapid at low acidity. At very high acidity probably the tin is relatively immune to attack, and almost complete polarization exists.

Preventive measures are use of cold-rolled tin plate (Type L, etc.), thorough exhausting, effective sealing of the cans, acidifying of fruits of low acidity, avoiding presence of sulfur or sulfite in the syrup on the fruit canned, provision of ample head space for H_2, and storage of the canned food at low temperature.

Effect of Fill of Cans.—Every means available should be employed to reduce the amount of air in the can since oxygen accelerates the corrosion of tin plate. Filling the can as completely as consistent with effective sealing reduces the head space and the volume of air contained therein; however, if the product is inclined to form hydrogen swells, the head space should be fairly deep in order to provide space for evolved hydrogen gas.

Preheating.—Canned apples are particularly active on the plate. It has been demonstrated by Huenick, Kohman, and others that the pulp of this fruit contains a relatively large amount of air, which is not usually removed by exhausting in the usual manner. This fact explains the customary practice of preheating the prepared fruit before placing in the can. Several other methods of pretreatment are in use (see Chap. XI).

The removal of air from apples by heating in dilute brine at 120°F. has been studied by Huenick, who finds that the following amounts of air are obtained from the fruit heated at 120°F. for the respective lengths of time indicated. The volumes of air are expressed in percentages of the total volume of the fruit. Heating for 20, 60, 120, 180, and 240 min. yielded 8, 8+, 9, 10, and 12 per cent of air, respectively. He recommends 20 minutes' heating at 120°F. as sufficient for practical purposes, as higher temperatures cause browning, but the fruit may be held at this

temperature overnight without injury. Dilute brine (3 per cent salt) is preferable to water, because slight browning of the edges of the pieces is liable to occur in water. The air may also be removed by subjecting the fruit to a high vacuum in a liquid such as water or dilute brine. Kohman recommends storage of the fruit for several hours in warm, dilute brine to permit removal of the oxygen in the tissues by respiration.

Exhausting.—Thorough exhausting of canned fruits serves the same purpose as preheating, *viz.*, the expulsion of air from the fruit and liquid. A long exhaust at a moderate temperature is much more effective in expelling air than a short exhaust at a high temperature.

Usual Method.—The usual style of exhaust box is heated by live steam, which gives a relatively high temperature, usually above 200°F. If open cans of fruit are subjected to a long period of exposure to the direct steam, the fruit in the top of the can becomes softened. If softening is avoided by a short exhaust, 2 to 4 min., air is not effectively expelled, even though the liquid in the center of the can may reach 165 to 175°F., because this short period of heating does not heat the fruit thoroughly.

An improvement over the usual method of exhausting consists in placing lids on the filled cans, in clinching the lids to the cans by passing them through the first rolls of a double-seamer and exhausting the cans in hot water. This permits escape of air from the can but prevents direct contact of steam with the fruit. This can only be done safely with lids equipped with rubber gaskets because paper gaskets are liable to become wet and crumpled during the final seaming operation and thus imperfectly sealed.

Exhausting in Water.—Exhausting in water at 185 to 190°F. permits of more careful control and does not result in softening of the fruit in the top of the can. Bigelow (1922) recommends a 6- to 8-min. exhaust in a hot-water exhaust box about 20 ft. long and wide enough to permit 10 No. 2 or 6 No. 10 cans to be carried abreast through the exhaust box by means of a suitable belt. The water level is at about 1½ in. below the tops of the cans and is maintained at 180 to 190°F.

Vacuum in Cans.—Bigelow recommends that exhausting should be so conducted that the vacuum in the cans after sterilizing and cooling to room temperature will be for No. 10 cans about 8 in., for No. 3 cans 12 to 15 in. and for No. 2 cans 20 in. Some canners desire a vacuum of only 5 in. in a No. 10 can. If the vacuum is much in excess of the above amounts, the cans may show excessive paneling, and if the vacuum is much less it may indicate the presence of an excessive amount of air.

Vacuum Sealing.—It is possible to remove air from fruit and liquids by treatment under a high vacuum. It is also possible to seal cans *in vacuo*. Therefore it is probable that canned fruits and vegetables could be thoroughly exhausted under a vacuum and vacuum sealed without use

of the present method of exhausting by heat. The method is already in use for brineless corn, juices, canned dried prunes, coffee, and salmon and is being used also in a semicommercial manner for a number of other products.

Sealing in Inert Gases.—A process of checking corrosion has been developed in New York by Rector and Tenney and described in *The Canning Age*. The filled cans are first subjected to a vacuum to withdraw air, a neutral gas (CO_2) is admitted, and this gas is then removed under a vacuum and fresh gas again admitted. This process is repeated several times, and the can is finally sealed with the neutral gas filling the head space of the can. The process was developed primarily for dry or semidry products, but it is stated that it can also be applied successfully to foods packed in syrup or brine. The pressure inside the can is equal to atmospheric pressure, and for this reason the tendency to form leaks is reduced. The neutral gas used does not favor corrosion.

Importance of Effective Sealing.—Not only must the air be effectively removed from the can and contents before sealing, but its entrance must be prevented after sterilization by perfect sealing of the cans.

Cans equipped with paper gaskets may be sealed tightly enough to exclude microorganisms but still admit air slowly. The gasket in such cases acts as an air filter, and such cans are commonly known as "breathers." Rapid corrosion usually follows, and the blackening of corn in some cases is attributed to this cause. The remedy lies in rolling the seams so tightly in the double seamer that air cannot enter. Bigelow (1922) states that the can factories' end of the can is usually airtight because the cans are sealed in a dry plant under carefully controlled conditions, while the canners' end of the can is the one most likely to be loosely sealed, and recommends storing the cans with the canner's end downward so that the paper gasket is wet by the syrup or brine and the seal made more effective. Paper gaskets are seldom used at present for canned fruits.

The rubber composition gasket is less apt to permit air to enter, but if imperfectly sealed, admits not only air but microorganisms as well. Imperfect sealing therefore becomes evident at once by the appearance of swells and bacterial spoiling.

Effect of Temperature of Storage.—Like all other chemical reactions the rate of corrosion of tin plate is more rapid at high than at low temperatures, and the storage of canned fruit in hot warehouses is therefore to be avoided.

Cooling.—If the cans are packed into boxes while still hot or stacked closely together in the warehouse before cooling, they remain warm for several days, with consequent excessive corrosion. Prompt cooling is therefore advised.

Effect of Character of Tin Plate.—Ordinary tin plate is known as coke plate and carries about 1½ lb. of tin per base box. A grade of tin plate known as Charcoal-A, or Char-A, used rather extensively for the preparation of cans used for fruit canning, carries about 2½ lb. of tin per base box, and for very acid products it is to be preferred to the coke plate. Recently, a new cold-rolled plate known as "Type L" plate (or by similar names) has been perfected and generally adopted. It is purer than ordinary plate, softer, and more homogeneous. It is very resistant to corrosion.

It has been recognized that the tin coating is not perfect and that rather numerous small areas exist in which the steel plate is exposed; usually these exposed areas are very small. Bigelow (1922) states that there are hundreds of these exposed areas on the surface of a single can and that increasing the weight of the tin coating does not eliminate these exposed areas.

The coating of the tin plate with lacquer, while it reduces the total amount of tin that goes into solution, greatly increases the tendency for the formation of pinholes. Kohman attributes this condition to slow disappearance of the oxygen in the lacquered can with consequent prolonged contact of the acid juice and tin with oxygen. In the plain tin can the oxygen rapidly combines with the tin plate over a wide surface, or combines with hydrogen, and action is therefore not excessive at any one point.

Testing Tin Plate.—It is sometimes desirable to test tin plate in order to determine the completeness of the coating of the steel plate with tin. This can be done by filling several cans with the following solution: water 1 gal., concentrated hydrochloric acid 1 cc., potassium ferricyanide 5 grams, and enough gelatin to cause jelling of the solution on cooling. A blue color will develop where the steel plate is not coated with tin.

Tin in Canned Foods.—All canned foods contain some tin in solution or in combination with the product. At one time a federal regulation placing the maximum tin content of canned foods at 300 mg. of tin per kilogram was enforced but at the present time food inspection officials do not attempt to apply the rule rigidly.

It has been proved by Bigelow and others that most of the tin in such foods is not to be found in the liquor but in the drained solids. The analyses of Table 37 taken from Bigelow's published results will indicate the relation of the tin content of the liquor and the solids.

Asparagus after 8 months' storage contained 280 mg. of tin per kilogram and after 31 months, 470 mg.; Lima beans after 9 months storage contained 80 mg. of tin and after 33 months, 173 mg.; wax beans contained after 3 months, 93 mg. and after 30 months, 347 mg. of tin per kilogram.

TABLE 37.—TIN CONTENT OF SOLIDS AND LIQUOR FOR SEVERAL IMPORTANT CANNED FOODS
(Tin reported in milligrams per kilogram, or parts per million)
(*After Bigelow*)

Product	Tin in liquor	Tin in drained solids	Total tin
Cherries	52	163	107
Cranberries	33	254	170
Raspberries	39	294	194
Peaches	86	251	193
Pears	99	151	130
Plums	43	180	125
Shrimp	67	381	224
Spinach	35	131	86
Asparagus (1 year)	252	489	433
String beans (1 year)	97	442	299

Storing Foods in Open Cans.—Many housewives and others firmly believe that food stored in an open tin can overnight contains dangerous amounts of tin. Bigelow reports in *Bulletin* 2 of the *National Canners' Research Laboratory* the results of a number of experiments upon the rate of solution of tin by various products in open cans. Some of the data appear in the following table:

TABLE 38.—RATE OF SOLUTION OF TIN DURING STORAGE OF FOOD IN OPEN CANS
(In milligrams per kilogram)
(*After Bigelow*)

Product	Tin on opening	Tin after 1 day's storage	Tin after 2 days' storage	Tin after 3 days' storage
Apples	59	81	91.5	129
Corn	12	15	14.0	11
Sauerkraut	44	51	74.0	113
String beans	144	138	143.0	160
Pumpkin	314	312	360.0	407
Tomatoes	68	69	93.0	143
Pineapple	75	97	102.0	158

The rather rapid solution of tin between the second and third days in some cases was due to fermentation or decomposition in other ways by microorganisms. In general it may be stated from these data that the amount of tin dissolved on standing in the open can is small and that the

current fear of food that has been allowed to stand in the can overnight is unfounded.

FLAT SOURING OF CANNED FOODS

The ends of a can which has undergone flat souring appear normal and the can is not noticeably under gas pressure but is sour in taste or at least altered in taste.

Corn.—The first investigators to publish data on the flat souring of canned corn were Prescott and Underwood, who studied the souring of corn in Maine canneries. The authors spent an entire packing season in a cannery in order to study packing methods and conditions and found that cans which did not give visible evidence of spoiling were sterile and that spoiled cans contained living organisms or gave unmistakable evidence of bacterial action. They isolated pure cultures of eleven bacilli and one micrococcus and of these organisms eleven formed spores, one produced gas and all except one produced acid. Prescott and Underwood stated that flat souring of corn is more common than swelling and that the latter condition develops only under exceptional conditions. They were able to reproduce the flat souring by inoculation of sterilized cans of corn with pure cultures of most of the organisms studied. Numerous investigations have been made in recent years upon the flat souring of corn (see also section on Thermophiles).

Other Vegetables.—Asparagus canners in California have experienced some loss through the development of flat sours, in some cases caused by thermophiles.

Spinach is packed so tightly into the cans that heat penetration is greatly retarded and sterilization is occasionally not complete; for this reason flat souring in addition to gaseous spoilage may occur.

Pumpkin and sweet potatoes occasionally undergo flat souring. Because of the poor heat conductivity of these two products, they are difficult to cool and for this reason are particularly favorable for the growth of thermophiles. Nearly all canned vegetables are subject to flat souring, if conditions are favorable (see following section).

Thermophiles.—Bigelow and his coworkers have demonstrated that much of the flat souring of canned vegetables, particularly corn and pumpkin, is due to the growth of thermophilic bacteria, which develop at relatively high temperatures only, usually above 100°F. When canned vegetables are not well cooled and are allowed to stand in large stacks with the cans piled so closely together that rapid radiation of heat is prevented, the contents of the cans remain at the incubating temperature for thermophilic bacteria long enough for spoiling to occur. This condition has developed frequently in the past, but now canners realize more generally the danger of such practice and loss from this cause is decreasing.

Bigelow and Esty (1920), Cameron, and others have made extensive thermal death point investigations upon a number of resistant thermophilic bacteria in media of different hydrogen-ion concentrations. One thermophile, No. 26, withstood a temperature of 100°C. (212°F.) for 1,260 min. (21 hr.) and 115°C. (239°F.) for 80 min. in corn juice. A heating of 3½ hr. at 100°C. was required to destroy the spores of the least resistant of 14 other organisms reported upon, and 21 hr. at 100°C. for those of the most resistant strain. Recently J. R. Esty stated in a lecture that one culture withstood nearly 72 hr. at 100°C. or 1½ hr. at 250°F.

These investigators found that the hydrogen-ion concentration of the medium exerts a marked influence on the thermal death point of thermophiles. Table 39 contains data which illustrate this effect. Of the vegetables given in the table, corn possesses the lowest acidity (highest pH value) and pumpkin the highest hydrogen concentration (lowest pH value). The data show that the spores in most cases in pumpkin juice were killed in about one-sixth the time required for those in corn juice. This fact illustrates in a very striking manner the fallacy of specifying processing times for a given product based upon data obtained for another product of different composition.

A similar relation probably holds for most other microorganisms causing the spoiling of canned foods.

Thermophiles are spore bearing. Some species are facultative thermophiles growing normally above 100°F. but capable of growing at about 70 to 160°F. Others are obligate thermophiles growing at about 110°F. to about 170°F.; these are in general much more heat resistant than the facultative thermophiles. It is practically impossible to sterilize foods heavily contaminated with spores of the obligate thermophiles. Control lies in preventing their entry into the product.

Some thermophiles are facultative anaerobes and a few are obligate anaerobes.

Some thermophiles form gas, *viz.*, carbon dioxide and hydrogen. One forms hydrogen sulfide gas, which reacts with iron dissolved from the tin plate to give black ferrous sulfide.

The obligate thermophiles are less resistant to acid than the facultative thermophiles and develop best at pH 6 to 8 and prefer starchy products such as corn. However, some of the facultative thermophiles have been encountered in canned tomatoes or tomato juice of low acidity and in very ripe pineapples. Cameron, Esty and their associates have given a great deal of attention to the thermophiles capable of growing in canned tomatoes and tomato juice.

In testing canned foods for the presence of thermophiles cans of the food product may be incubated at 110 to 120°F. for about 3 weeks. If gas formers are present the cans will swell. If facultative, flat-sour thermo-

philes are present the pH value will drop to pH 4.8 or even lower. The liquid may be tested with bromocresol green in such cases. If obligate thermophiles of the flat-sour type are present, the pH value will usually drop to about 5.2, the juice or brine being tested with bromocresol purple. The hydrogen electrode may be used for more accurate determination of pH value.

In an extensive survey of thermophilic spoilage in canneries in the Middle West, Cameron and associates of the National Canners' Association found that the usual sources of contamination were tanks of hot water or hot brine, or other equipment maintained at a temperature high enough for growth of thermophiles. The wood of wooden tanks used for blanching water or hot brine in some cases became heavily seeded with thermophile spores. The raw products, corn and peas, carried very few thermophilic spores. However, asparagus may carry considerable numbers of resistant spores from the soil, it has been found in California. In respect to flat souring and sulfide spoilage (H_2S-forming thermophiles) of corn and peas, Cameron recommends that wooden tanks for blanching or for preparation of hot brine or water be replaced with resistant metal or glass-lined metal tanks and that the hot liquids be not carried over from day to day but be made fresh each day. Liquids must not be allowed to stand warm in pipe lines, pumps, etc., between shutdowns, as spores may be formed in enormous numbers. Such equipment should be flushed out thoroughly before beginning the day's operations.

Sugar may be a source of thermophilic spores since in sugar manufacture opportunity exists in some stages of the operations for growth and sporulation of thermophiles. Some of the spores may carry through into the finished product. Sugar is now bought, for use in corn and pea canning, on the basis of its content of thermophile spores. The National Canners' Association has specified the method of estimating the number of

TABLE 39.—EFFECT OF HYDROGEN-ION CONCENTRATION ON THE THERMAL DEATH POINT OF THERMOPHILIC ORGANISMS

(Temperature 115°C., 239°F.)

(*After Bigelow and Esty*)

Culture	Number of spores per cubic centimeter	Minutes required to destroy spores heated in									
		Corn juice PH 6.1		Pea juice PH 6.3		Sweet potato juice PH 5.0		String bean juice PH 5.0		Pumpkin juice PH 4.5	
		+	−	+	−	+	−	+	−	+	−
1503	150,000	60	63	45	48	28	30	20	25	10	10.5
4109	40,000	58	60	40	45	25	28	15	18	10	11.0
1390	60,000	55	58	35	40	25	28	6	7	6	7.0
1549	50,000	35	40	25	30	15	18	10	12	5	6.0
1492	10,000	30	35	12	15	9	10	6	7	4	5.0

such spores and their type, *e.g.*, flat sours, hydrogen sulfide formers, and gas formers.

NONPOISONOUS GASEOUS SPOILING

Gaseous decomposition occurs with all canned goods under favorable conditions. Gaseous spoilage may be classified as nonpoisonous and poisonous.

Fruits.—Examination of swelled cans of fruit usually reveals the presence of yeast cells and evidence of alcoholic fermentation. Yeasts are very rapid producers of carbon dioxide, which accounts for the frequent bursting of spoiled cans of fruit. In a very few instances only are bacteria found to be the cause of spoiling of canned fruits, although occasionally found in pears and less frequently in pie-grade peaches, both being fruits of low acidity.

Spoiling of canned fruit by yeast usually signifies leaky cans or gross carelessness in sterilization. An exception to this statement is the spoiling of solid-pack pie fruit, in which heat penetration is so slow that the centers of No. 10 cans may not reach a temperature fatal to yeasts, if the sterilizing process used for syrup-packed fruits is applied. Also with overripe pie fruit the pH value may be so high as to permit growth of spore-bearing bacteria.

Vegetables.—The first important bacteriological investigation of swelled canned vegetables was conducted by H. L. Russell at the University of Wisconsin in 1895, at a time when the canners of Wisconsin were losing large quantities of canned peas. They knew very little about bacteria and placed the blame for the spoiling upon various factors later proved to have little or no relation to the problem. From swelled cans of peas Russell isolated two species of bacteria, of which one produced typical swells when inoculated into sterile cans of peas. He recommended the increase of the processing temperature from 232 to 242°F. and the time from 26 to 28 min. Previous to the adoption of this recommendation the number of swells had been about 5 per cent of the total pack; after its adoption, this type of spoiling was reduced to a negligible amount.

Prescott and Underwood at the Massachusetts Institute of Technology in 1896 and 1897 made important contributions to the knowledge of the swelling of canned corn. Their investigations, while more extensive than those of Russell, yielded similar results. Other canned vegetables, notably spinach, undergo gaseous spoiling, if not well sterilized.

Because of the low oxygen content of canned foods, spoiling is usually caused by anaerobes or facultative anaerobes. Of the spore-bearing gas formers, *Bacillus sporogenes* and *B. welchii* which produce a very disagreeable putrid odor, are among those most commonly found in swelled

cans of vegetables. Organisms of the *B. coli* group frequently cause gas formation in leaky cans, but owing to the fact that they do not form spores, they very rarely survive processing.

The heat-resistant organisms occurring on peas were studied extensively at the Michigan Experiment Station by Ruth Normington, who described seven strains of spore-bearing, heat-resistant, gas-producing bacteria. One of these (organism *C*) closely resembled *B. botulinus*, another (organism *B*) conformed to the description of *B. subtilis*, and a third (organism *E*) resembled *B. ramosus*. She found that pure cultures of *B. subtilis*, *B. ramosus*, *B. ruber*, *B. prodigiosus*, *B. viscosus*, and some of the organisms isolated by her from peas produced gas in peas but not in other media. All of Miss Normington's spore bearers withstood 110°C. (230°F.) for 10 min., and most of them survived 120°C. (248°F.) for 10 min. She advises the use of pressure sterilization in preference to processing in boiling water.

As previously stated certain obligate thermophiles produce CO_2 and H_2 in canned foods at low acidity. They are anaerobic and very resistant to heat.

BOTULISM AND BACILLUS BOTULINUS

(Clostridium botulinum)

The term "botulism" is used to designate a type of poisoning caused by the toxin of *Bacillus botulinus* (*Clostridium botulinum*). According to Dickson the word "botulism" was coined early in the nineteenth century by physicians in southern Germany to apply to a peculiar type of food poisoning resulting from the ingestion of spoiled sausages. Synonymous terms are "allantiasis" and *Wurstvergiftung* (sausage poisoning). So-called "ptomaine poisoning" is often botulism.

Bacillus botulinus (*Clostridium botulinum*) has become of very grave concern to the canning industry because of the outbreaks of botulism from both commercially canned and home-canned products. In recent years commercially canned foods have not caused outbreaks of botulism; but home-canned foods continue to do so occasionally.

History.—The first recorded case of botulism, according to Dickson, occurred in 1735 in Germany, and following this date references in the medical literature of Germany to botulism are frequent. Dickson summarizes the German reports as follows:

1793–1820, 76 cases, 37 fatal
1820–1822, 98 cases, 24 fatal
1822–1886, 238 cases, 94 fatal
1886–1913 about 800 cases, about 200 fatal
Total 1793–1913 about 1,212 cases, about 365 fatal
Fatality, about 30.1 per cent.

Nearly all of these outbreaks were from meat products.

The most interesting of the German outbreaks occurred in Darmstadt in 1904 and was reported by Fischer. It was caused by eating salad prepared from home-canned green beans and was, until that date, the only case reported in European literature in which poisoning was caused by other than animal products.

K. F. Meyer has summarized the history of botulism in the state of California from 1900 to 1920 as follows: 39 outbreaks among human beings with a probable total of 139 cases, of which 94 were fatal, or equal to a mortality of 72.3 per cent; 42 outbreaks among fowls from eating canned foods; and 18 outbreaks of forage poisoning among animals, a total of approximately 161 outbreaks.

It has frequently happened that housewives or others have opened a jar or can of food and have, after noting a peculiar odor, thrown the material to the chickens with fatal results to the fowls. In one case 643 chickens were killed from eating garbage and other kitchen refuse into which had been thrown four jars of spoiled home-canned beans.

Other cases could be enumerated, but these will suffice to indicate that the organism is by no means confined to meat products and, in fact, has occurred, in the United States at least, rather frequently in home-canned vegetables and fruits. This latter situation is to be expected because of the frequent lack of knowledge of the principles of sterilization on the part of home canners.

About 1919 to 1924 a tremendous amount of basic and applied research was conducted on *Clostridium botulinum* in California by K. F. Meyer of the University of California, E. C. Dickson of Stanford University, J. R. Esty of the National Canners' Association, J. C. Geiger of the U. S. Public Health Service, and their associates. As a result the properties of the organism are now well understood (see bibliography at end of this chapter for details).

Distribution of the Spores in Nature.—K. F. Meyer in research conducted at the University of California has proved that the spores of *Bacillus botulinus* are widely distributed in nature and that they occur very frequently in soil samples representing practically every state in the union, although a larger percentage of the samples from Pacific coast states than from eastern states were positive. He has demonstrated that samples of virgin soil contain the organism more frequently than samples of cultivated soil from the same regions. He has recovered the organism from practically 100 per cent of the samples of virgin soil from the Yosemite Valley and from a number of similar samples from Yellowstone Park. It is therefore evident that *B. botulinus* is not necessarily a filth organism.

Burke recovered the organism from a spoiled jar of home-canned string beans, from the soil in the garden in which the beans were grown,

and from the vines themselves. Meyer reports a similar chain of evidence from a case in northern California and has recovered the organism frequently from fresh fruits and vegetables.

It is probable that the failure of early investigators to recover the organism from the soil and from fresh foods was due to faulty technique. By incubating large samples of soil anaerobically in a suitable nutrient medium it has become possible to produce enrichment cultures from which the organism may be recovered or its toxin demonstrated if the spores are present.

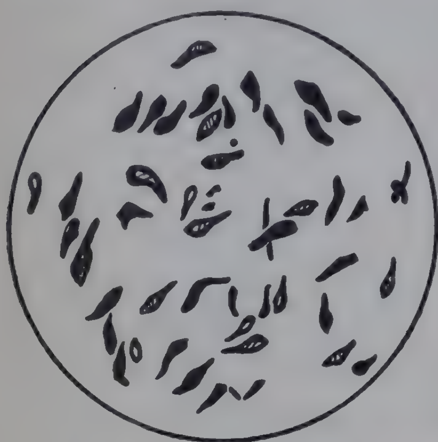

Fig. 46.—Bacillus botulinus (*Clostridium botulinum*) with spores. (*After Dickson.*)

Relation of Botulism to Forage Poisoning.—Graham and his associates have repeatedly demonstrated that one type of so-called forage poisoning in animals is caused by *B. botulinus* toxin formed in the forage. Ensilage and musty hay or straw have been frequent causes of this type of poisoning. It is probable also that a disease known as "limber neck" in chickens may be caused by ingestion of botulinus toxin in the food.

Cultural Characteristics and Morphology.—Van Ermengem, a Belgian scientist, was the first to prove *Clostridium botulinum* to be the primary cause of botulism in man. At Ellezelles, in 1894 he isolated the organism from ham preserved in brine, which had caused the illness of 23 persons and the death of 3. He found the organism to be a large Gram-positive, sporebearing, anaerobic bacillus, with large, oval spores, usually occurring at the ends of the cells, giving them a club-shaped appearance (see Fig. 46). He gave it the name of *Bacillus botulinus.* He found that infusions of the macerated ham and bouillon cultures of the organism produced the typical symptoms of botulism in guinea pigs, rabbits, cats, pigeons, and monkeys and proved that the bacillus itself is a saprophyte and that the poisoning is due to a toxin which is formed when the organism is grown under anaerobic conditions.

Other investigators have confirmed Van Ermengem's findings and added a great deal to our knowledge of this interesting bacillus (see in particular the publications of Meyer, Dickson, and Esty).

Odor.—In most media it produces a very characteristic penetrating butyric odor, similar to that of rancid butter or Roquefort cheese. This is most pronounced in meats and peas and is least noticeable in string beans and fruits. Cases are on record, however, where the odor of the food causing botulism was not objectionable.

Although an anaerobe, *Cl. botulinum* can be grown in cultures exposed to the air in symbiosis with aerobic organisms.

Effect of Sugar and Salt.—Dickson obtained growth and toxin formation in 65 per cent cane sugar solution. Wyant and Normington report growth of the different strains in 10 per cent brine, although toxin formation may not occur at such high salt concentration.

Optimum Reaction.—The bacteria grow more readily in media containing glucose than in glucose-free media. Although it will develop in slightly acid media, the organism prefers a medium of neutral or faintly alkaline reaction, and a small amount of sodium chloride (0.5 per cent) favors its growth. Gas is produced abundantly in glucose media, and in glucose agar shake cultures the organism causes breaking of the agar from gas formation.

Size.—The bacilli are large, 4 to 6 by 0.9 to 1.2μ, have slightly rounded ends, and may arrange themselves in pairs, end to end. They are slightly motile and possess from 4 to 8 flagella arranged around the periphery.

Beef-heart media and brain media are excellent for growth of the organism.

Types of Clostridium Botulinum.—Burke at Stanford University found that there are at least two distinct types of *Cl. botulinum* which form different types of toxin. Type *A* antitoxin, for example, will not protect an animal against type *B* toxin but will protect against type *A* toxin if given simultaneously with the toxin. She has designated these as type *A* and type *B*, and finds that the antitoxin of type *A* will neutralize the type *A* toxin but not type *B* toxin, and vice versa. Type *A* is that usually found on the Pacific slope and type *B* in the eastern United States. A number of different strains exist in each group. In general, type *A* produces a more virulent toxin than type *B* and is usually more resistant to heat, but in other respects than those noted above the two types are similar. More recently a type *C* has been found; it is responsible for botulism in ducks feeding in shallow water on decaying organic matter. Type *D* is responsible for botulism in livestock in South Africa.

The Toxin.—Liquids in which *B. botulinus* has been grown can be filtered to remove all organisms, and the filtrate will be toxic to animals when injected or when fed. The toxin, unlike most other bacterial toxins, is not destroyed in the digestive tract but is absorbed by the blood stream.

The antitoxin will protect against the toxin if administered with it, but apparently it is of no avail if given after botulism symptoms have appeared.

Resistance of the Spore to Heat.—The characteristic of most importance to the canner is that of heat resistance. Van Ermengem in 1897 and several later investigators determined the death temperature of *B. botulinus* spores to be 80°C. (176°F.), and textbooks have given this as the death temperature of the spores.

Dickson in 1917 sounded a warning against the belief that *B. botulinus* is easily killed by heat and called attention particularly to the danger of the so-called "cold-pack" method of home canning of vegetables. He inoculated jars of peas, beans, and corn prepared according to the usual cold-pack recommendations. The peas and beans were heated in boiling water for 120 min. and corn 180 min. in accordance with the cold-pack method. Within 3 weeks all of the jars had undergone a gaseous fermentation, a number were leaking, and the contents of the jars caused typical botulism symptoms and death when fed to guinea pigs and chickens. Much work by Meyer, Esty, and others has confirmed and extended these findings. In some cases the spores have withstood over 5 hr. heating at 212°F.

A case of botulism in chickens developed in California in 1918 from feeding spoiled home-canned string beans processed in jars by the fractional sterilization method of heating for 1 hr. in boiling water on each of 3 successive days. The ineffectiveness of the fractional sterilization is attributed by Burke to the fact that heating the spores to 100°C. (212°F.) greatly retards their germination. In one case the spores germinated only after 20 days' incubation following heating to 100°C. Meyer reports cases of delayed germination of more than one year's duration. Burke investigated the heating of ten strains of *B. botulinus* and found considerable variation in their resistance. One strain survived 4 hours' boiling, and one 10 lb. pressure (239°F.) for 20 min. and 15 lb. pressure (250°F.) for 10 min. Meyer and Dickson also have found very resistant strains.

From the published data it would appear to be desirable to employ for products of low acidity such processing times and temperatures that the center of the container is held at 240°F. for at least 30 min. or processed for equivalent times at other temperatures.

In 1917 the writer inoculated peas, string beans, corn, and fish in quart jars with spores of five strains of *B. botulinus* from brain medium. To one set of jars of each product was added 3 per cent brine containing 5 oz. of lemon juice per gallon, and to similar jars of each lot was added 3 per cent brine containing no lemon juice, all jars being processed in boiling water for 60 min. The acidified samples kept perfectly, after 6 months' incubation showed no evidence of decomposition, and were not toxic to guinea pigs. The peas, fish, and corn samples which were not acidified spoiled and developed the characteristic butyric odor and gas formation typical of spoilage by *B. botulinus*. The liquids from the corn and peas caused death of guinea pigs in 24 hr. The liquids in the jars contained a large Gram-positive bacillus with oval spores, *i.e.*, the typical club-shaped cells of spore-bearing *B. botulinus* bacilli. The writer with Fong and Liu extended these experiments to include a variety of food products and rather a wide range of pH values, with results similar to those mentioned above.

Dickson, Meyer, Esty, Weiss, Wyant, and others have confirmed the effect of pH value upon the death temperatures of the spores of *B. botulinus*. The sensitiveness of the organism to common organic acids probably explains why acid fruits are so readily sterilized and so rarely cause botulism.

Resistance to Sodium Benzoate.—In tests conducted by the writer, it was found that *Cl. botulinum* was readily inhibited by $\frac{1}{10}$ per cent sodium benzoate at pH values below 4.5, but with increase of pH value above 4.5 the amount of benzoate required to prevent growth and toxin formation rapidly increased, and at pH values above 5.0 it is impractical to attempt to preserve foods in this manner.

Classification of Outbreaks According to Food.—Meyer recently listed the outbreaks of botulism from various home-prepared foods as follows: string beans, 66 outbreaks; corn, 25; pork products, 12; spinach, 11; asparagus, 10; beets, 9; peppers, 6; beef products, 5; sea food, 5; pears, 4; apricots, 3; figs, 3; okra, 2; chicken, 2; beans, 2; miscellaneous, 15. Under miscellaneous are listed apricot butter, cauliflower, celery, home-brew, milk, mushrooms, egg plant, olives, pickles, pimentos, salad dressing, succotash, tomato relish, turnips, and vegetable soup mixture.

A few years ago a fatal outbreak occurred in the Middle West from imported, Italian canned challots (a vegetable similar to the onion), although since that outbreak the Italian canners have instituted safe canning procedure under K. F. Meyer's guidance.

Among commercially canned foods pork and beans, ripe olives, spinach, potted meat, peas, and fish have been involved. No outbreaks have occurred from these or any other American commercially canned foods in recent years, because processing times and temperatures now in use completely destroy the spores if such should be present.

Other Information on Cl. botulinum.—The organism seldom grows below pH 4.5.

The guinea pig is one of the most suitable test animals as it is very sensitive to the toxin. It is advisable to feed rather than inject the suspected food, as injection may introduce organisms that will kill by infection and growth in the blood stream or tissues of the animal.

Spoiled foods should never be tasted. Cases are on record in which a housewife has tasted the spoiled home-canned product, later cooked the product, and served it to the family. She developed botulism and the family were not affected. Boiling had destroyed the toxin. A good rule is to boil all home-canned vegetables thoroughly before tasting or serving, since boiling for a sufficient period will destroy the toxin. But since heat penetration may be slow, rather prolonged boiling is necessary for such home-canned foods as spinach and potatoes.

Frozen-pack foods may contain the spores but unless allowed to spoil completely after thawing do not contain the toxin. Danger from this

source is probably very remote, as usually other organisms monopolize the field and exclude *Cl. botulinum.*

The presence of oil greatly increases the resistance of the spores to heat.

The spores may be detoxified without seriously injuring them at about 180°F. This provides a simple means of securing toxin-free spores for experiments in processing, use of preservatives, etc.

Tomato sauce of pH 4.4 caused one outbreak, as did also, in one case, home-brew made of home-canned fruits, sugar, water, home-canned tomatoes, etc.

Growth of the organism in experimentally canned products may occur with very little to no toxin production.

ANAEROBIC NONTOXIC SPOILAGE

Anaerobic thermophilic spoilage with formation of CO_2 and H_2 or of H_2S has been mentioned. Anaerobes resembling *Clostridium botulinum* but forming no toxin sometimes cause spoilage of nonacid canned foods. *Cl. sporogenes* is occasionally encountered in such spoilage. Some strains possess heat resistance similar to that of *Cl. botulinum;* consequently, they provide a valuable source of test organisms.

BYSSOCHLAMYS FULVA

Recently a costly form of spoilage of canned fruits caused by a heat resistant mold has appeared in England. The organism withstands 86 to 88°C. for 30 min. in some fruit syrups. The contents of the can are partially liquefied by the organism. It has been named *Byssochlamys fulva* and has been described by Olliver (see reference in the bibliography at the end of this chapter).

LIVING ORGANISMS IN SOUND CANNED FOODS

It is often assumed that canned foods which do not undergo visible spoiling are sterile, but investigations have proved that this assumption is not correct in many cases.

Meats.—Weinzirl states that in 1900 Vaillard in France examined bacteriologically a large number of samples of canned meats, many of which were edible and to outward appearance sterile, and found living bacteria in 70 to 80 per cent of them.

Sadler found that normal cans of fish frequently contain living organisms. Hunter and Thom found 224 out of 530 cans of commercially packed salmon to contain living spores of a resistant bacillus. There was no evidence of spoiling in any of these samples.

Weinzirl at Harvard examined a large number of samples of canned meats, including sardines, and found that 19.5 per cent of 273 apparently sound commercial samples contained living organisms. Most

of the organisms were spore-bearing aerobes. Canned oysters, clams, salmon, and soups were found sterile in most cases.

Milk.—Sweetened condensed milk was found by Weinzirl to contain *Bacillus mesentericus* and *B. subtilis*. This product is not sterilized at a high temperature. Evaporated, unsweetened milk was sterile in most cases, because it is given a severe sterilization under pressure.

Fruits.—Most fruits are processed at 100°C. (212°F.) for a short period only. Therefore, it might be expected that spore bearers would survive and be found in commercially canned fruits.

In the examination of 104 cans of normal appearance, Weinzirl found living mold spores in 4 cans and spore-bearing bacteria in 31 cans. *B. subtilis* occurred 14 times, *B. mesentericus* 10 times, *B. cereus* 8 times, *B. vulgatus* 3 times, and thermophiles 9 times. Yeasts were not found. The fruit in all cases was normal in appearance and showed no evidence of bacterial growth.

Beresford at the University of California found viable spore-bearing bacteria in olives processed at 212 to 230°F. but none in olives sterilized at 240 to 250°F. for 20 to 30 min.

Vegetables.—Weinzirl reports results from the examination of commercially canned vegetables very similar to those given above for fruits. No yeasts were encountered in 370 samples of commercially canned vegetables of normal appearance. Molds occurred in 2 per cent of the cans and spore-bearing bacteria in 20.5 per cent. Much the same types of bacteria were found as listed above for fruits.

Incubation at 37°C. did not cause these organisms to develop in the unopened cans, probably because of lack of oxygen. The bacteria were found to develop readily in the vegetables under aerobic conditions; and apparently the absence of oxygen is the principal limiting factor, although Bigelow, Esty, and others have shown conclusively that canned vegetables containing living thermophiles will keep perfectly unless stored at temperatures above 100°F.

LABORATORY EXAMINATION OF SPOILED CANNED FOODS

While it is not the function of this text to present full directions for the laboratory examination of food products, a very brief summary of recommended procedure for examining spoiled canned foods is probably justified. For details the reader is referred to the *Journal of Official Agricultural Chemists*, 428–449, 1936.

Treatment of Unopened Container.—The top of the can should be sterilized. If the can is a swell, it must not be heated, as it may cause bursting. Such cans should first be scrubbed with soap and water if dirty. The top may then be sterilized with 1:1,000 mercury bichloride. If the can shows no pressure, the top may be flamed with a Bunsen burner,

or a few cubic centimeters of alcohol may be placed on the top and burned off.

Fellers recommends that a hole about 1½ in. in diameter be cut in the top with a flame-sterilized awl or sterilized cheap can opener. The can is covered with a sterile Petri dish cover if not sampled at once.

If the can is a hydrogen swell, it should be examined for perforations.

Liquid samples may be taken by pipette with wide opening. Solid samples may be taken with a large sterile cork borer or sterile piece of glass tubing. Tanner recommends samples be taken well below the surface of the contents.

The culture medium will vary according to the nature of the spoilage organisms, although Cameron states that there is much less need for special media than many bacteriologists believe. He recommends tryptone agar for flat-sour organisms. It consists of tryptone, dextrose, agar, and water containing a small amount of bromocresol purple. Incubation is at 55°C. Flat-sour colonies show a yellow halo.

He states that liver broth reinforced with peptone and dipotassium phosphate is satisfactory for anaerobic bacteria, either mesophiles or thermophiles. The medium is heated before inoculation to expel oxygen and is stratified with sterile vaseline or sterile, plain agar after inoculation. Incubation is at 55°C. for thermophiles and 37°C. for mesophiles. The agar is split by gas formation if viable anaerobes are present. He recommends for trial also a medium made of 2 per cent dry liver and 5 per cent corn meal. It is autoclaved at 15 to 17 lb. steam pressure. Growth is evidenced by gas formation, as the medium is very thick in consistency.

In order to test for the presence of hydrogen sulfide-forming *Cl. nigrificans*, a yeast-water agar containing 0.1 per cent sodium sulfite and 3 per cent sucrose is used. In each tube is placed a small, clean iron strip.

James finds that tomato juice broth agar is satisfactory for many organisms from spoiled acid foods. He also uses malt extract-tomato juice agar. For lactic acid bacteria Vaughn of the University of California finds diluted, filtered tomato juice an excellent medium. For molds and yeasts there are no better media than grape juice diluted one-half with water or filtered, undiluted orange juice. These juices are easily sterilized at 100°C.

Dunbar recommends incubating tubes for thermophiles at 52 to 55°C. instead of the 45°C. used by some, because at 45°C. some mesophiles may grow. He points out also that, if the medium is incubated at 37 to 38°C., there is very rapid growth of blood temperature organisms, which may crowd out bacteria that develop best at lower temperatures. Therefore, he recommends an incubation at 30 to 32°C. for mesophiles.

Occasionally, although the can is swelled and microscopical examination shows enormous numbers of bacteria, growth in culture media is

negative because the products of metabolism have killed the organisms.

For testing the toxicity of spoiled canned foods for botulinus toxin small amounts of the contents are fed to guinea pigs or to white mice or both. Typical symptoms develop, usually within 24 hr., and death ensues if much toxin is present.

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CHAPTER XV

UNFERMENTED FRUIT BEVERAGES[1]

Annual Production.—The production of fruit juices has increased greatly in recent years owing to the phenomenal increase in the canning of various juices since 1929, in which year tomato juice was first canned in important amount. It is estimated that approximately 20,000,000 cases of canned fruit juices are now (1937) produced annually in the United States; or about 100,000,000 gal., which is about twice the annual consumption of wine in the United States.

In Table 40 are given data on the annual United States production of canned and bottled fruit juices.

TABLE 40.—TOTAL UNITED STATES PRODUCTION OF CANNED AND BOTTLED FRUIT JUICES
(In cases of 24 qt.)
(From *Western Canner and Packer, October*, 1936)

Year	Apple juice bottled	Grape juice bottled	Grapefruit juice canned	Orange juice canned	Pineapple juice canned	Tomato juice canned
1929	No data	1,000,000*	205,000	....	....	185,000
1930	No data	1,000,000*	179,934	37,552	....	1,338,964
1931	No data	1,000,000*	416,683	99,209	....	3,476,244
1932	No data	1,000,000*	288,324	36,362	....	4,583,635
1933	No data	1,000,000*	728,691	110,597	700,000	4,170,794
1934	No data	1,000,000*	629,576	342,678	2,000,000	5,703,920
1935	1,250,000	1,000,000	2,675,586	1,107,299	2,500,000	8,170,640
1936	1,450,000	1,000,000	2,227,074	1,462,452	5,000,000	13,104,809

* Approximation.

In addition to those listed in the table, other juices are canned commercially in moderate quantities for which production data are not readily available. The most important are canned loganberry, apricot, blackberry, cranberry, and prune juices. Canned loganberry juice has proved particularly popular, and its production should increase. Recently apple juice has been canned successfully. In special cans and

[1] The writer is greatly indebted to M. A. Joslyn and G. L. Marsh for use of much of the information presented in their *Circular* 344, Production of fruit juices, University of California, 1937.

with proper introduction as a first class product to the consuming public, it should become at least as important as canned grapefruit juice, or even canned pineapple juice in popularity.

In addition to bottled and canned fruit juices a large quantity of orange juice is consumed fresh at juice stands and in the home. Large amounts of orange concentrate and of orange syrup are used as a base for carbonated bottled beverages and for a bottled noncarbonated beverage; in both cases the syrup or concentrate is diluted greatly with water before bottling, and the products are preserved with sodium benzoate.

Various carbonated bottled drinks (soda water) are consumed in great quantities in the United States. While some of these bear "fruity" names, usually they contain little to no fruit juice. The writer has long believed that there is a great opportunity for improving these beverages and for providing an important outlet for fruits by including an appreciable amount of fruit in those beverages which carry fruit labels; such as strawberry, raspberry, grape, lemon, orange, and lime (see *Bulletin* 365, *Circular* 313 and *Circular* 344 of the College of Agriculture, University of California, for further discussion of this suggestion).

Formerly it was customary to clarify fruit juices either by filtration or by fining before bottling. At present most of the preserved juices on the market are cloudy or pulpy.

GENERAL METHODS AND EQUIPMENT

Fruit juices are most attractive when first expressed from the fresh fruit and any treatment applied to preserve or clarify them results in more or less injury to quality. Preservation must be accomplished with as little injury as possible to the fresh flavor and other desirable qualities of the product.

Choice of Fruit.—Fruit that is to be used for the preparation of juice should be of marked and agreeable flavor and aroma, must have "character," should not be flat or insipid in flavor, and should be of tart flavor, that is, moderately rich in acid. In addition the juice should retain its character satisfactorily during processing and during storage after bottling or canning.

Harvesting and Transportation of the Fruit.—Fruit juices must be prepared from sound fruit only and even slight fermentation or mold growth which would not seriously injure some fruits for other purposes, will spoil the flavor of the juice for beverage purposes. This fact makes it necessary also to use only clean boxes, free from mold, for picking and transporting the fruit to the factory.

The fruit should be picked at the proper stage of maturity for the preparation of juice, which will vary with the variety. Thus loganberries

should be picked when they have become "dead" ripe, *i.e.*, soft ripe, for they are then at their optimum color and flavor. Vinifera grapes, with the exception of the Muscat variety, should be picked when slightly underripe, in order that the juice may not be too low in acidity and too rich in sugar. For the same reason apples should not be allowed to become overripe and mealy in texture before crushing.

Importance of Sorting and Washing.—Sorting is usually desirable and frequently necessary before the fruit is crushed, and can be accomplished in the same manner as described elsewhere for tomatoes.

Most fruits accumulate some dust in the field or during transportation and for this reason, should be rinsed thoroughly by sprays of water before crushing. Fruit that has become contaminated by moldy fruit, as is sometimes the case with apples stored in bins, requires vigorous washing. Oranges in some sections develop a sooty mold deposit on the surface, which can only be removed by scrubbing and washing.

Berries and other soft fruits can be washed satisfactorily as they pass beneath water sprays on a woven metal conveyer.

Choice of Metal.—The crusher should be of such material that it does not react with the juice. Iron or steel rolls or knives are liable to cause darkening of some juices by the solution of a small amount of iron, which reacts with the tannin and coloring matter of the juice to produce a black or dark-brown color.

Stainless steel is extremely resistant to the action of fruit juices and should be used for crushers, reamers, pipes, bulk pasteurizers, and other equipment if the volume of output warrants the expense. Aluminum bronze is satisfactory for filter frames. Tin-copper bronze free of zinc is usually satisfactory for cocks and pipe couplings. Nickel and monel metal are satisfactory for some juices. Copper and tin are objectionable because even small concentrations of their salts adversely affect the flavor and color of most juices and catalyze undesirable changes. Iron and steel are very undesirable.

Grape crushers should be made of resistant bronze or other alloy or metal not attacked by the juice. For further discussion see papers of Mrak and Leroux, and Mrak and Cruess on corrosion of metals by juices.

Preparing Fruit for Juice Extraction.—The extraction of juice from fruit usually involves crushing and pressing, although there are exceptions, notably apricots, peaches, and citrus fruits.

The method of extraction depends upon the structure of the fruit, location and character of the tissues in which the juice is located, and the character of the finished juice. In some fruits, as in apples and grapes, the juice is located throughout the fruit and is readily recovered by crushing and pressing. In others, as in citrus fruits and pomegranates,

the juice-containing tissue is surrounded by a thick skin which contains soluble substances of objectionable flavor or color; therefore, the juices of such fruits must be extracted in such manner as to avoid extracting the undesirable substances from the skins.

From apricots, peaches, and tomatoes pulpy juices are prepared; consequently, the raw or the cooked fruits are passed through some sort of pulper to give a purée-like liquid containing a large proportion of suspended, finely divided solids.

Undue aeration must be avoided during the extraction of juices from fruits that have not been heated to destroy enzymes, since destruction of Vitamin C and oxidative changes in flavor are very rapid in some juices, particularly citrus, apple, and tomato juices. These changes are catalyzed by traces of iron and copper in solution.

Crushers are of various types. That used for grapes consists of two fluted-metal rollers which revolve toward each other. They are set at such distance apart that the grape berries, but not the seeds, are well crushed. Paddles revolving in a perforated cylinder below the rollers knock the crushed berries through the holes in the lower half of the cylinder and "kick" the stems out the open end of the stemmer cylinder. In the Garrola crusher the grapes are crushed by impact against rapidly revolving paddles inside a perforated cylinder. The crushed berries and juice are pumped from the crusher to a tank or directly to the press.

Apples are prepared for pressing by treatment either in an "apple grater" or in a hammer mill. The grater consists of a revolving metal cylinder about 8 to 12 in. in diameter, on the surface of which are imbedded shallow knives extending the entire length of the cylinder. Parallel to the cylinder is a set of upright knives, or a curved fluted-metal plate toward which the cylinder revolves. The fruit on passing through the apparatus is grated, rather than crushed. The upright knives or curved plate are on heavy springs to permit passage of rocks or other hard objects. Fineness of grating is regulated by adjusting the distance between the cylinder and upright knives or plate. This apparatus is also fairly satisfactory for grapes, berries, and pears.

At present the apple grater is being replaced by a special hammer mill. "Hammers" (flail-like pieces of metal) attached to a revolving cylinder crush the fruit finely by impact against a metal surface. The hammer mill gives a larger yield of juice than does the grater because of more thorough grinding of the fruit (see Fig. 48).

Citrus fruits require special equipment and procedure as described in the section on citrus juices. Ordinary crushing and pressing are not employed. Tomatoes are usually pressed without crushing, or they are passed between revolving and fixed metal fingers that tear them coarsely.

Pressing.—Juice is extracted from most fruits by presses of many different designs, in which pressure is obtained in several different manners.

Rack and Cloth Press.—Probably the most satisfactory press for general use is that known as the "rack and cloth press," which is used for apples. In this style of press the crushed fruit is placed in heavy cloths of coarsely woven, heavy cotton fiber, to a depth of about 2 to 3 in., and the edges of the cloths folded toward the center, as shown in Fig. 47. A wooden rack made of heavy, hard, wooden slats is placed on the folded cloth containing the fruit and a second cloth containing crushed fruit is placed on this rack. The process is repeated until the press is filled. The several cloths of fruits and the racks taken together are known as a

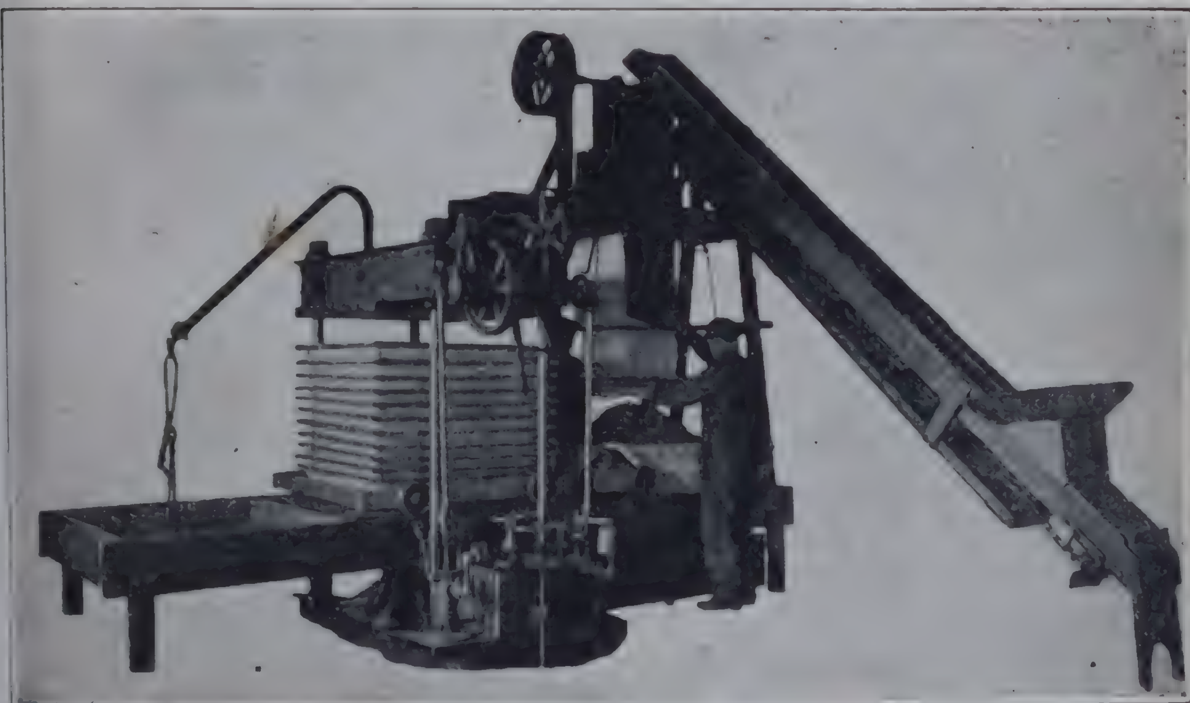

Fig. 47.—Large fruit crusher and hydraulic press. (*Courtesy The Hydraulic Press Manufacturing Company.*)

"cheese." Pressure may be applied by any one of the methods described below, although the usual method is by hydraulic pressure.

Basket Press.—In the basket press, very generally used for grapes, the crushed fruit is placed in a heavily reinforced wooden basket of cylindrical form, as shown in Fig. 49.

Beam Press.—Pressure may be applied to either the rack and cloth press or the basket press in one of several ways, but the simplest method is by means of a long wooden beam weighted at one end. Pressure can be regulated by the amount of weight placed on the beam and by its length.

Screw Press.—The screw press represents the first improvement upon the beam press and is used most commonly in conjunction with a basket. The screw may be operated by a lever or by cog gears.

Hydraulic Press.—Hydraulic pressure can be applied by means of oil or water and a pump. The liquid is pumped into a heavy walled "ram," or cylinder, attached to either the top or the bottom of the press. The pressure that can be applied is in the ratio of the diameter of the pressure cylinder piston to that of the pump, and for very heavy pressures the diameter of the pump must be small and that of the cylinder large. Pressure must be increased at such a rate that the juice may escape from the cloths without subjecting the cloths to such pressure that they are ruptured.

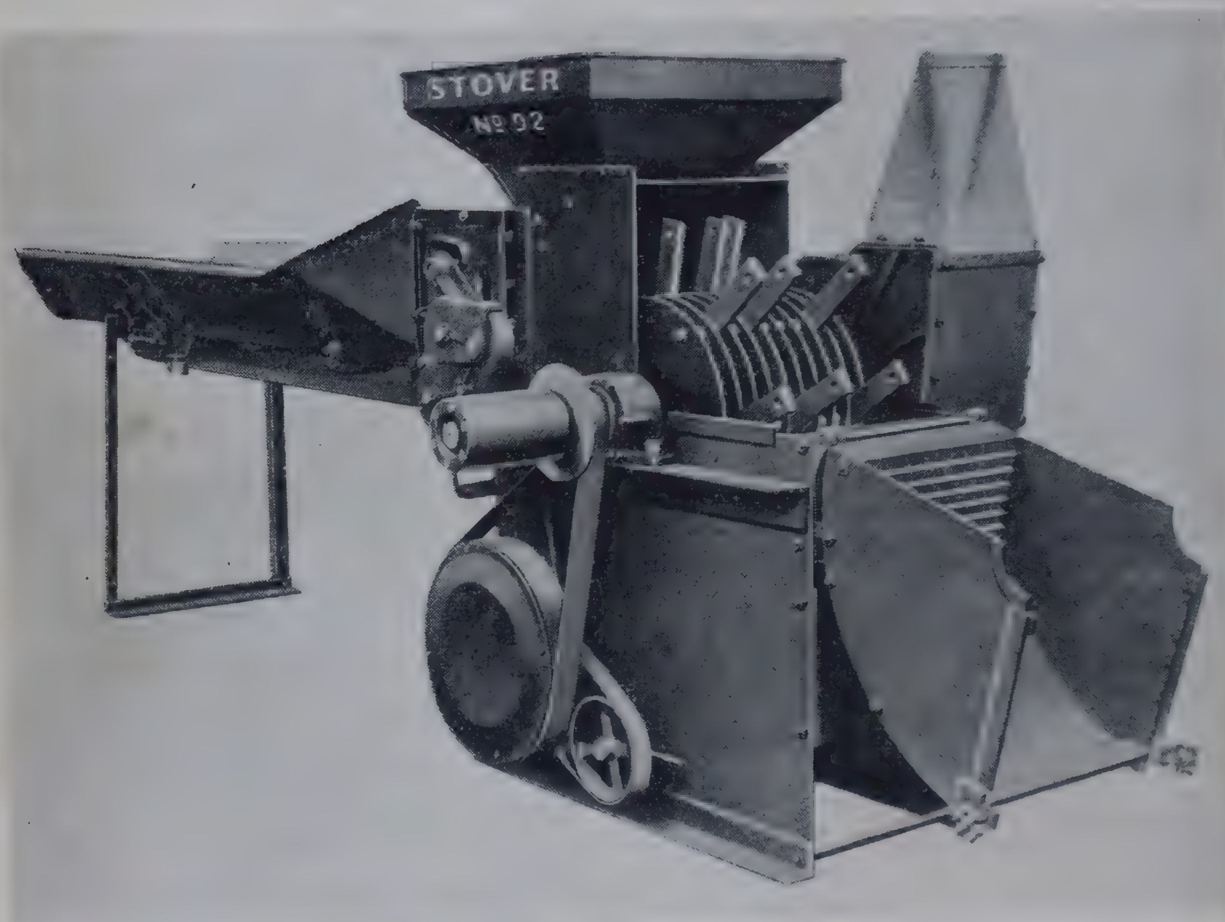

Fig. 48.—Hammer-mill type apple crusher.

Continuous Press.—All of the presses described above are discontinuous in action. Continuous presses are available, into one end of which the crushed, or in some cases the whole, fruit is fed and to which pressure is applied, the pomace (pressed pulp) discharging continuously at the opposite end of the press. The juice escapes through openings in the bottom of the press. In principle the press consists of a cone or cylinder with a perforated bottom, hopper, and restricted adjustable opening at the end opposite the hopper, and a heavy conical screw which revolves within the cylinder. The fruit enters the hopper at the large end of the press and is forced through the cone toward the smaller end. This press has proved fairly satisfactory for the pressing of lemons for the

manufacture of citric acid and for pressing fermented crushed grapes, but it is not desirable for use in pressing most fruits because it tends to grind the fruit to a fine pulp, much of which passes through the openings in the bottom of the press with the juice. A special form of this press is used for tomatoes (see Fig. 50).

METHODS OF PRESERVATION OF FRUIT JUICES

Several methods are in commercial use for the preservation of fruit juices. The most important of these are discussed below.

Fig. 49.—Basket press operated by hydraulic pressure. (*Courtesy The California Press Manufacturing Company.*)

Pasteurization.—Pasteurization as applied to fruit juices means the destruction, by heat, of all microorganisms capable of increasing in the juice and of causing spoiling. It usually does not kill the spore-bearing organisms, such as *Bacillus subtilis, B. mesentericus,* etc., but these organisms and most other spore-bearing bacteria as well cannot grow in acid fruit juices, and consequently their presence is of no practical significance. Pasteurization of still (noncarbonated) juices need only be at such a temperature and for such a time that yeasts and molds are destroyed. Yeast is killed by heating for a few minutes at 140 to 150°F. and resistant mold spores will require in most cases a temperature of 175°F. for 20 min. Molds require oxygen for growth, and for this reason heavily carbonated juices can be pasteurized safely at 150°F., which

destroys yeast cells. Most still juices must be pasteurized at 175°F.; juices of high acidity may be pasteurized at a lower temperature, 160 to 165°F.

Effect of Carbon Dioxide.—Experiments have been made by J. H. Irish and the writer upon the effect of carbon dioxide upon pasteurizing, in which it was found that carbonating at from 10 to 60 lb. pressure did not noticeably reduce the death temperature of typical fruit juice organisms, such as yeast, mold spores, *B. coli*, *B. subtilis*, etc. The carbon dioxide, however, prevented growth of surviving mold spores. It was found that 30 min. pasteurization at 65°C. (149°F.) in all cases prevented subsequent development of mold spores in samples carbonated and heavily inoculated before pasteurization.

Bulk Pasteurization.—It is often necessary to store fruit juices in bulk in large glass carboys or in barrels to permit settling or shipment in bulk. Two types of pasteurizers, which may be designated as (1) continuous and (2) discontinuous, are used for this purpose.

The continuous pasteurizer consists of a single metal tube or series of small metal tubes, through which the juice flows and is heated to the desired temperature by a steam or hot-water jacket. Block tin, aluminum and, silver-lined copper are commonly used for the purpose; but stainless steel is much to be preferred because of its resistance to corrosion.

Heating by Steam.—The use of steam is somewhat objectionable because it does not permit of very exact regulation of the temperature and is liable to cause scorching or overheating of the juice.

Heating by Water.—If the heating tubes of the continuous pasteurizer are surrounded by water, it is possible to regulate the temperature very closely. The temperature of the water surrounding the heating tubes need not be more than 3°C. (about 6°F.) above the temperature of the juice, and therefore there is little danger of overheating the juice.

Discontinuous Pasteurizers.—The discontinuous pasteurizer consists of a steam-jacketed kettle, or of a tank equipped with steam coils, in which the juice may be placed and heated to the desired temperature. It is objectionable because it is liable to cause local overheating of small portions of the juice in contact with the heating surface, to expose the juice to the air and oxidation during pasteurization, and to prolong heating with injury to color and flavor.

Heating by Electricity.—In the Electropure apparatus the fruit juice is passed between carbon electrodes, and at the same time the juice is heated almost instantaneously to the desired temperature by passage of ordinary 110-volt 60-cycle alternating current. This method is easily regulated and avoids scorching since heat is generated by passage of current against the resistance of the juice; the electrodes themselves are not hot.

Flash Pasteurization.—Under usual factory conditions the juice in bulk pasteurization is passed, while still hot, directly into sterile barrels or large bottles for storage and remains hot in the barrels for 24 hr. or longer and in the bottles for 5 or 6 hr. This prolonged heating results in considerable injury to the flavor and the color of the product. Chace has devised a means of chilling the juice immediately after pasteurization by passing the cooled juice under aseptic conditions into sterile containers, preferably bottles, and sealing the containers with sterile corks or caps. Great care must be employed in order to avoid infection of

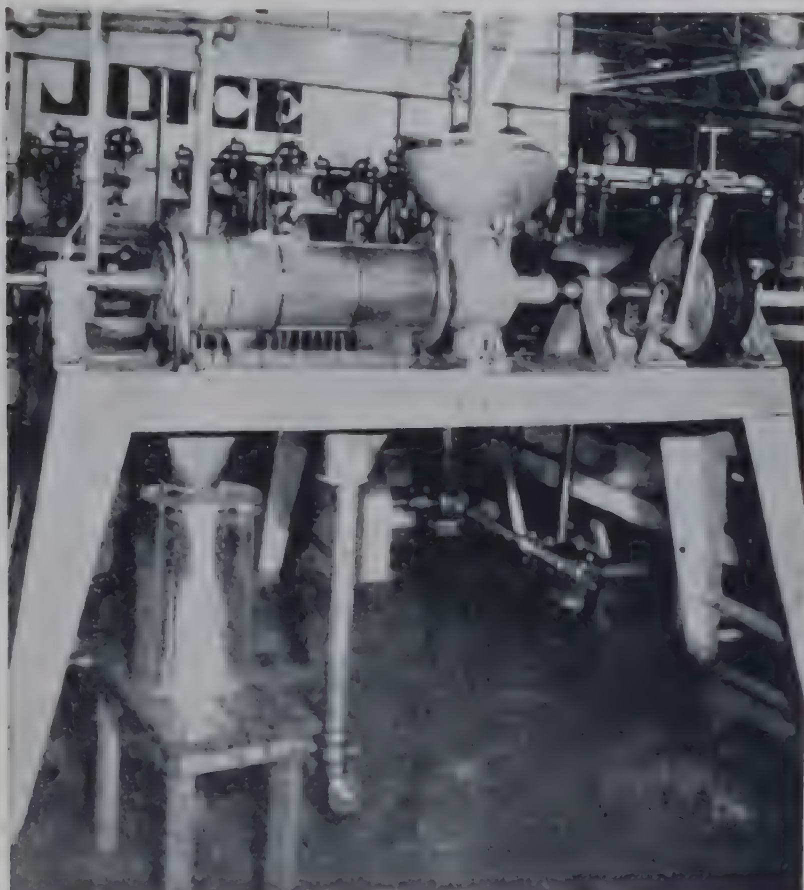

FIG. 50.—American Utensil Co. fruit-juice extractor. (*Photograph by Food Industries Journal.*)

the juice with mold or yeast, and it is doubtful whether the process will have wide application in factory practice. A temperature of 180 to 185°F. (about 82 to 85°C.) is used for a few seconds only, and therefore the juice suffers very little injury to flavor or appearance. This treatment is given to citrus juices and apple juice to inactivate enzymes as later described.

Pasteurization in Bottles and Cans.—After the juice has been filtered or otherwise treated to prepare it for bottling or canning, it is sealed in the final container and pasteurized, usually by immersion in water, which is heated to the desired temperature and for the desired length of time. One form of bottle pasteurizer consists of a shallow wooden vat fitted with

a steam coil and a perforated false bottom on which the bottles are placed in a horizontal position, covered with water, and heated to the pasteurizing temperature.

In large establishments continuous pasteurizers are used in which the bottles of juice are carried by a basket conveyer progressively through baths of water of increasing temperature and through baths of water of decreasing temperature to cool the juice. Cans are usually filled hot directly from a bulk pasteurizer; or are pasteurized in a continuous pasteurizer in much the same manner as canned fruit is processed.

Heat may also be applied to the bottled juice by sprays of water circulated by a pump. The temperature may be regulated so that the bottles are heated gradually to the pasteurizing point and cooled slowly by gradually reducing the temperature of the water, so that breakage is reduced to a minimum.

Relation of Factory Sanitation to Pasteurization.—Investigations at the University of California have demonstrated that the temperature necessary for pasteurization varies with the mass of the infection of the juice with yeast or mold.

Therefore all possible precautions should be taken to exclude microorganisms from the juice at all stages of the process. Press cloths unless washed immediately after use and dried at once will become "sour," *i.e.*, infected with large numbers of yeast cells and mold spores. The lines, pumps, tanks, filling machines, and all other equipment that come in contact with the juice must be kept scrupulously clean and steam or hot water used frequently and generously in the cleaning and sterilizing of such equipment. Crushers are particularly liable to develop yeast and mold if not thoroughly cleaned after use.

Bottles, cans, and bottle caps should be sterilized before use, caps in particular being a very prolific source of mold infection in bottled beverages.

Preservation of Fruit Juices by Chemical Preservatives.—Although it is not an ideal method of preservation, large quantities of apple juice are preserved with benzoate of soda. Other fruit juices are sometimes preserved with sulfurous acid.

Benzoate of Soda (and Benzoic Acid).—The active preservative principle of benzoate of soda is the undissociated benzoic acid, not the sodium ion. The salts of benzoic acid are more readily soluble than the acid, and for this reason the sodium salt is employed in preference to the acid.

The percentage of sodium benzoate that may be used in the preservation of foods was at one time limited by pure food and drug regulations to $\frac{1}{10}$ per cent, but at the present time more than this amount may be used, provided the label bears a statement giving the percentage con-

tained in the product. Fruit juices can, in practically all cases, be preserved satisfactorily by the addition of $\frac{1}{10}$ to $\frac{15}{100}$ per cent of the benzoate. The benzoic acid exerts a selective action upon the organisms found in sweet cider, often preventing the growth of yeasts and molds, but permitting the development of vinegar and lactic acid bacteria.

Carbonating increases the toxicity of benzoic acid upon the spores of *Bacillus subtilis*, as shown by investigation by J. H. Irish on the carbonating of grape juice. pH value greatly affects the preservative action of sodium benzoate, the preservative action being much greater at low than at high pH values.

Sodium benzoate possesses a disagreeable "burning" taste that is readily perceptible in juice containing $\frac{1}{10}$ per cent of the benzoate.

Sulfurous Acid.—Fruit juice can be preserved for more than a year by the addition of $\frac{1}{10}$ per cent of sulfurous acid (1,000 mg. per liter, or 1,000 p.p.m.), provided the juice is made from sound fruit and stored in clean containers at a temperature not above 60°F.

Sulfurous acid is very much more toxic to mold spores and vinegar bacteria than it is to yeast, in this respect differing from benzoic acid, which is more toxic to yeast than to vinegar bacteria.

Fruit juice may be preserved temporarily (from several days to 2 or 3 weeks) with concentrations of sulfurous acid considerably less than $\frac{1}{10}$ per cent, and small amounts of this preservative are often useful in preventing fermentation of juice during 1 or 2 days' settling after pressing, in order to aid in clearing. For this purpose 100 mg. per liter (0.01 per cent) of sulfurous acid is usually sufficient and does not noticeably affect the flavor of the product.

TABLE 41.—RATE OF DISAPPEARANCE OF SULFUROUS ACID FROM GRAPE JUICE
(*After Bioletti and Cruess*)

Time in hours	Total sulphur dioxide	Free sulphur dioxide
0.5	219	127
49.0	...	93
64.0	...	90
74.0	188	90
97.0	158	50
136.0	...	13
181.0	126	11

Disappearance of Sulfurous Acid.—Some of the preservative combines with the sugar and other compounds of the juice and in such a form is not perceptible to the taste and part of it either escapes into the atmosphere as sulfur dioxide or is oxidized to sulfuric acid, H_2SO_4. The preceding

table indicates the rate of disappearance of sulfurous acid from grape juice and the rate of conversion of free sulfurous acid into the combined form. Combined sulfurous acid has very little antiseptic value upon microorganisms, 6,000 parts per million (p.p.m.) of the combined form having less toxic action on yeast than 50 p.p.m. of the free sulfurous acid.

The presence of a very small concentration of sulfurous acid, *e.g.*, 50 to 100 mg. of sulfur dioxide per liter in fruit juice, greatly aids in the preservation of the fresh fruit flavor and color by reducing the tendency of the juice to oxidize. It cannot be used, however, in juice that is to be stored in tin or other metal containers since in contact with metal the sulfur dioxide is reduced to hydrogen sulfide with the development of a disagreeable flavor. Sulfurous acid can be removed by heating the juice to about 70°C. (about 160°F.) and passing through it a vigorous stream of air, or by passing steam through the juice under vacuum.

Sugar as a Preservative.—All fruit juices may be preserved by the addition of sugar or by increasing the natural sugar content of the juice by concentration. Such products are, however, fruit syrups and will be discussed fully in Chap. XVI.

Preservation by Low Temperatures.—When stored at 32°F. (0°C.), the temperature ordinarily employed in the cold storage of fruits, fruit juices either become moldy or undergo fermentation, and in order to prevent the growth of microorganisms, it is necessary to use temperatures below 25°F.

In experiments at the University of California (Cruess, Overholser, and Bjarnason), it was found that grape juice, apple juice, and berry juices could be held for at least 2 years at temperatures of 10 to 15°F. (about 5 to 8° below 0°C.) without noticeable loss of flavor, aroma, or color, where the juices were stored in sealed containers, such as lacquered tin cans or in bottles. The juices were not pasteurized.

It is believed that this method could be applied upon a commercial scale with marked increase in the consumption and popularity of unfermented fruit juices.

Recently fruit juices have been preserved by cold storage for shipment over a distance of 500 miles in glass-lined tank cars by precooling the juice to about 28°F. and placing it at once in well-insulated tanks of several thousand gallons' capacity each.

Preservation by Pressure.—Hite, Giddings, and Weakley found that grape juice in active fermentation could be sterilized by subjecting it to a pressure of 75,000 lb. per square inch for 30 min. and by a pressure of 30,000 lb. per square inch applied for a somewhat longer time. Apple juice was sterilized by 60,000 to 80,000 lb. pressure per square inch applied for 30 min., and actively fermenting sugar solutions were sterilized by 60,000 lb. pressure in 30 min.

In their experiments a small collapsible tin tube was filled with the fruit juice or other liquid, and the tube was sealed. The tube was then placed in a lead cylinder, which in turn was placed in a heavy-walled steel cylinder into which water or oil was forced by hydraulic pressure. In some of their experiments a pressure of 110,000 lb. per square inch was used.

The experimentors state that fruit juices preserved by this method were equal to the fresh fruit in flavor and general quality and that it would be feasible to build a machine in which juice could be sterilized in containers of larger size than those used in their experiments.

Preservation with Carbon Dioxide.—Fruit juices have been successfully preserved by special methods of carbonating. In the Ruef process the fruit juice is first filtered through a porcelain filter to remove most of the yeast cells, is then carbonated under aseptic conditions, and is bottled in sterile bottles. The method has not been applied commercially because of the great difficulty of completely excluding microorganisms.

In the Frank process, formerly in use for the preservation of "near beer," the liquid is placed in a heavy keg or other suitable container and subjected to a vacuum to withdraw most of the air from solution in the liquid. The liquid is then carbonated to a moderately high pressure, above 60 lb. per square inch, and is, after standing a short time, again placed under a vacuum and carbonated a second time. It is claimed that the repeated carbonating and treatment under vacuum destroy the microorganisms which would otherwise cause spoiling of the product.

Preservation by Close Filtration.—In Germany, America, Switzerland, and South Africa, fruit juices have been successfully preserved by filtration through "tight" pads such as the Seitz E-K filter pads under aseptic conditions into bottles sterilized with SO_2 solution. This procedure is in use in several plants in the United States (see Fig. 54). Experimentally, as previously mentioned for the Ruef process, juices have been rendered free of microorganisms by filtration through a fine-pored, Berkefeld, porcelain-filter candle.

The trend at present, however, is toward cloudy or pulpy juices. Also it has been found that by vacuumization and flash pasteurization the fresh flavor of juices can be retained rather satisfactorily.

Control of Enzymes.—Preservation of the flavor, aroma, color, and vitamin content of the fresh juice is dependent to a great degree on destruction of certain enzymes or inhibition of their activity.

Joslyn and Marsh have found that flash pasteurization at about 190°F. destroys the enzyme or enzymes responsible for many of the undesirable changes in flavor of citrus juices. Matthew and the writer found that small concentrations of sulfur dioxide also retarded these changes, indicating that, to some extent at least, oxidation is involved.

Apples contain a very active oxidase, making it desirable to flash pasteurize the fresh juice immediately after pressing, in order to minimize browning by destruction of the oxidase responsible for this change. Vitamin C is rapidly destroyed during darkening of fresh apple juice. Kohman has found that preheating crushed tomatoes to a temperature sufficient to destroy Vitamin C oxidase prevents loss of that vitamin during subsequent operations in preparing the juice (for further discussion of this point see Chap. XIX).

Subjecting freshly expressed juices to a high vacuum for 15 to 20 min. to remove dissolved and occluded oxygen before canning or bottling greatly reduces subsequent undesirable oxidative changes. In the canning of citrus juices deaeration in this manner is common practice. In some plants the vacuum is released with nitrogen gas instead of with air in order to still further minimize oxidation.

Vacuumizing bottles and cans before sealing is a common usage in the better juice-canning and bottling plants in order to reduce the amount of oxygen in the container. Juices should be canned or bottled promptly in order to avoid excessive changes due to enzymic oxidation.

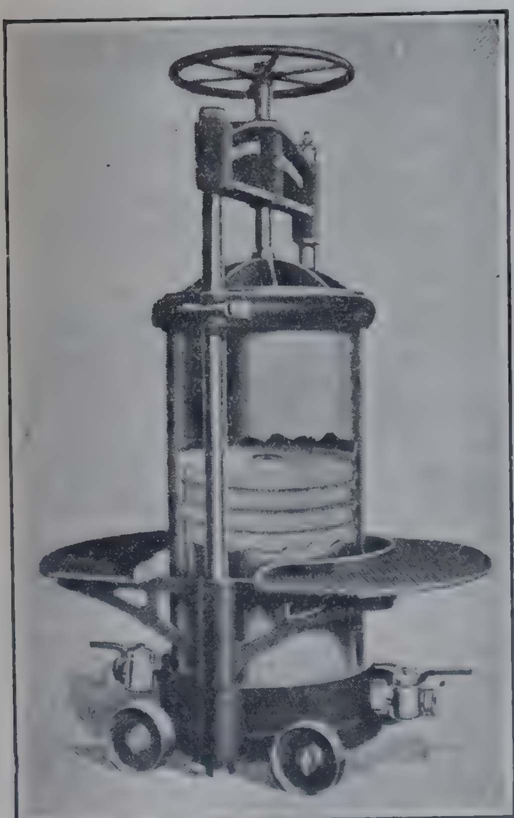

Fig. 51.—Large pulp filter for fruit juices showing filtering disks in place. (*Courtesy The Karl Kiefer Co.*)

In other words as many precautions as possible must be taken to curb enzyme action during the preparation of fruit juices and also to prevent their activity after canning or bottling.

THE FILTRATION OF FRUIT JUICES

Some fruit juices are improved in appearance by filtration or by other means of clarifying. The exceptions to this rule are citrus, apricot, peach, pineapple, pear, and tomato juices which are most popular in the cloudy condition.

The Bag Filter.—The simplest filter is that known as the bag filter, which is merely a conical bag made of heavy canvas, felt, or other heavy cloth. Unless the juice is mixed with infusorial earth or other clarifying material it does not usually yield a clear juice. This filter is useful for a preliminary treatment of juice to be filtered through a more effective type of filter.

Pulp Filter.—The usual form consists of an upright copper or stainless-steel cylinder which is filled with several thick disks of compressed

wood pulp or cotton fiber. Circular metal screens and metal plates are placed between the pulp disks and so arranged with regard to the juice supply pipe and outlet pipe that each disk acts as an individual filter. The juice is forced through the filter by gravity from a supply tank above the filter, or by means of a force pump. The filter mass or pulp must occasionally be removed and washed thoroughly and can then be formed into filter disks for use again. The clearness of the filtrate and rate of filtration depend to a large extent upon the pressure applied in forming the filter cakes. Thus through heavily pressed disks, filtration will be slower and the filtrate clearer than if the pulp is formed into cakes under low pressure.

For small-scale use a large suction funnel, in which a layer of pulp is packed as a filter mass, is satisfactory. It may be attached to a large wide-mouthed bottle and a suction pump.

Filters are also packed with short-fiber asbestos. The Seitz filter is of this type and consists of an upright chamber in which is enclosed a screen coated with a layer of asbestos fiber. The clearness of the filtrate can be regulated by the length of the fiber used. Short fiber mixed with ground asbestos or infusorial earth is used for producing a brilliantly clear filtrate, whereas the longer fiber asbestos is used for coarse filtration. The asbestos may be washed and used repeatedly.

Pad Filters.—Recently the pad filter, a form of filter press, has become popular in the wine and brewing industries for final or "polishing" filtration of wine and beer. It has been used also as previously stated for sterilization of fruit juices by complete removal of all microorganisms. The Seitz-pad filter is the best known of filters of this type and is widely used in Europe. The Ertel, an American pad filter, is also excellent.

The pad filter consists of a number of recessed metal frames between which are held thin pads made of pulp and asbestos fiber. The pads are purchased ready to use from the manufacturer and are discarded after use. Pads are of varying degrees of porosity. Ordinarily the juice first is given a rough filtration in some other form of filter, and the pad filter is used as a means of making the juice brilliantly clear.

Filter Press.—The usual filter press consists of a series of metal or wooden plates between which are placed pieces of canvas or other heavy cloth, each piece of canvas and pair of plates acting as an independent filter, although all of the plates are fed from a common source (see Fig. 52). Aluminum bronze has proved very satisfactory for construction of the plates and frames since it is resistant to corrosion and has sufficient strength for the purpose.

In operating the filter press some of the juice is mixed with a small amount of infusorial earth, which collects on the surface of the filter

cloths, forming a filter mass and effectively removing suspended matter from the juice.

Effect of Preliminary Heating on the Filtration of Juices.—Fresh fruit juice is rather slimy in character and extremely difficult to filter. Preliminary pasteurization reduces the viscosity of the juice and 24 to 48 hours' settling usually results in the coagulation of much of the protein of the juice and its elimination by settling, together with a large proportion of the suspended, finely divided pulp.

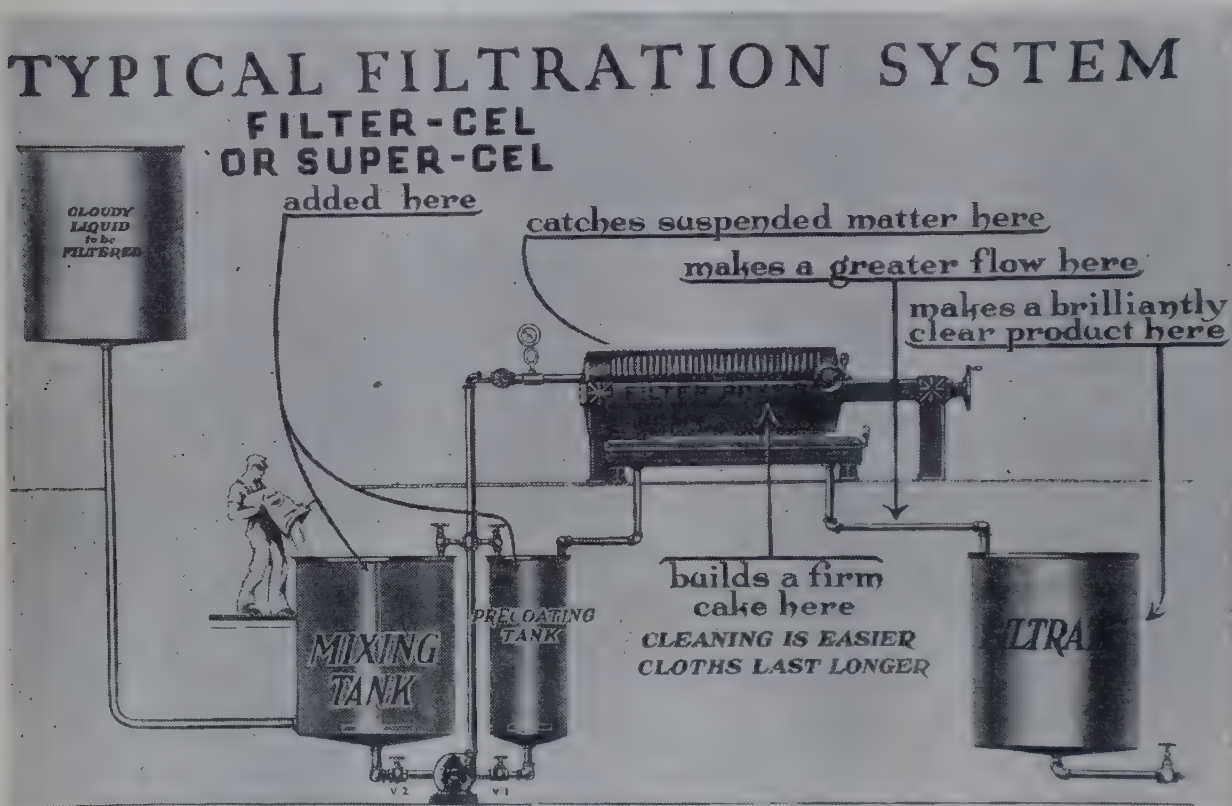

FIG. 52.—Schematic flow sheet for filtration of juices with filter aid. (*Courtesy Johns Manville Co.*)

Infusorial Earth as an Aid to Filtration.—Chace has described a process of clarification of pomelo (grape fruit) juice with infusorial earth and filtration. Some infusorial earth imparts a disagreeable flavor to juice, but Caldwell has found that heating the earth to dull redness volatilizes or burns the compound responsible for the undesirable change in flavor. He recommends the building up of a thick layer of the earth on a fine metal screen or heavy denim filter cloth in some form of filter press, and mixing with the juice to be filtered 5 or 6 lb. of the earth per 100 gal. In practice usually less than this is used. A commercial filter, the West Coast, makes use of a fine screen and infusorial earth. The producers of the infusorial earth are now in a position to furnish the incinerated earth in form suitable for the filtration of fruit juices.

Infusorial earth is mined as a white, friable, and easily powdered rock, the principal deposit and mine being located at Lompoc, and elsewhere

in California. The rock is ground to a fine powder and separated into powders of different degrees of fineness by sifting and air flotation. It is known in the trade as Filter-Cel, Hy-Flo Supercel, Dicalite, etc.

CLARIFICATION OF FRUIT JUICES BY SETTLING, BY FINING, AND BY ENZYMES

It is possible in certain cases to clarify fruit juices by settling, with or without pasteurization as the juice may require, or by the addition of fining materials.

Settling.—Frequently fruit juices after pasteurization will become clear during storage, the length of storage necessary depending upon the variety of juice and other conditions. Thus pomegranate juice will become clear within 24 hr. after pasteurization, while grape juice usually requires several months' settling.

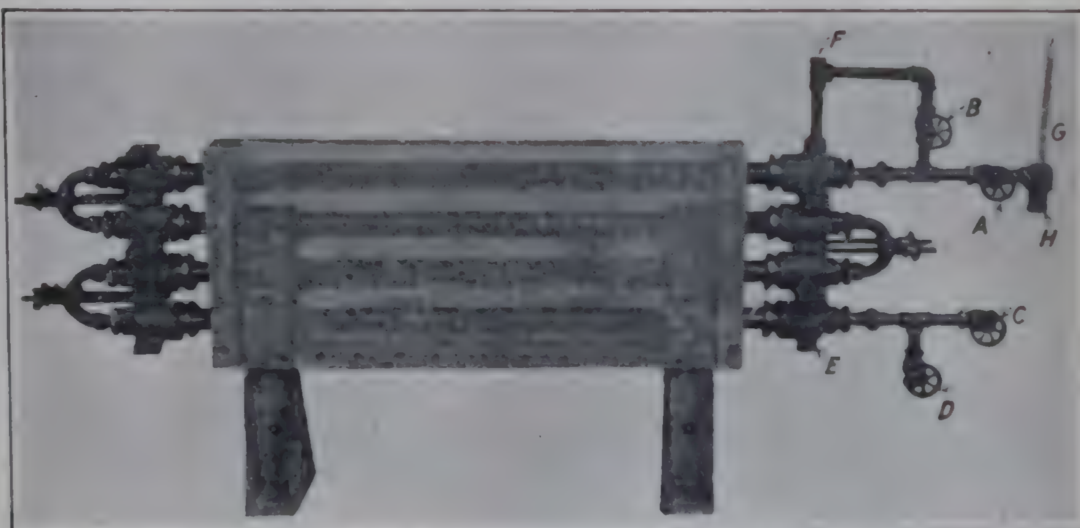

Fig. 53.—Continuous pasteurizer for heating fruit juices. (*Courtesy The Hydraulic Press Mfg. Co.*)

In the commercial manufacture of grape juice settling of the pasteurized juice greatly facilitates filtration by eliminating much suspended matter.

Use of Finings.—Some juices, which do not settle satisfactorily during storage and are difficult to filter, can be clarified by the addition of a fining agent. This agent may be defined as a substance which, when added to the liquid to be clarified, will form a precipitate which settles and carries with it the finely divided particles responsible for the cloudy appearance. The fining materials most commonly used for fruit juices are egg albumen, casein, Spanish clay, bentonite clay, and infusorial earth.

Egg Albumen.—This is purchased in dry granular form and is dissolved in warm water by soaking and agitation. The temperature of the water must not be high enough to cause coagulation of the albumen, and the best results are obtained with a 2 per cent solution. Red juice

from Vinifera grapes (European varieties) normally requires about 100 to 150 grams of albumen (dry basis) per hectoliter (about 3⅓ to 5 oz. per 25 gal.), and Muscat grape juice requires about 200 grams of albumen per hectoliter. Preliminary tests with small lots (500 cc. each) of the juice should be made to determine the amount of finings required. The required amount of the finings solution is mixed with the juice, and the whole is heated to a temperature of 160 to 175°F., coagulating the egg albumen, which settles rapidly during subsequent storage. Some of the albumen apparently remains in unstable solution for several days but finally precipitates. The juice should be heated with the finings to a temperature several degrees above that to be used for the bottled juice, in order to avoid further coagulation of albumen and clouding in the bottle.

Casein.—Commercial casein is prepared from skim milk by precipitating the curd (casein) with dilute hydrochloric or other acid; separating of the curd from the whey; and washing, drying, and grinding the resulting casein. It is soluble in alkalies and is precipitated from solution by acids. For the clarification of fruit juices a 2 per cent solution is prepared by soaking the casein in a small amount of ammonium hydroxide solution (concentrated ammonia diluted with 10 to 20 parts of water) and boiling until fumes of ammonia are no longer perceptible. The solution is then diluted to 2 per cent casein content and is added to the juice as noted above for egg albumen. The acid of the juice precipitates and coagulates the casein, and the coagulum usually settles completely within 24 to 48 hr. after pasteurization. It is less likely than egg albumen to precipitate in clarified juice after bottling, and it exerts considerable bleaching action on red juices.

Spanish Clay and Bentonite Clay.—Spanish clay is a gray to brown clay, from Lebrija, Spain. It is used in fining wines and has been used in clarifying fruit juices. It is ground in water to give a finely divided suspension, containing 10 grams of clay per 100 cc. (a 10 per cent solution). This is added to the juice in amounts corresponding to 1,000 to 1,500 grams of the dry clay per hectoliter (about 35 to 50 oz. per 25 gal.). Bentonite, a volcanic clay, is used in much the same manner as Spanish clay. It is more easily prepared for use since it quickly takes up water to form a smooth colloidal suspension. It is used as a 5 per cent suspension in water.

In using either clay the juice should be heated to 140°F. or higher in order to hasten coagulation and settling.

Fruit juice may also be clarified by heating with 1 to 5 per cent of infusorial earth and settling.

Juices successfully clarified by means of any of the above fining materials can be filtered easily and yield brilliantly clear filtrates. How-

ever, in the clarification of fruit juices upon a commercial scale, filtration is in general the most satisfactory method.

Use of Enzymes.—It has been found by Kertez of the New York Agricultural Experiment Station that apple juice and grape juice can be clarified by treating the fresh juice with an enzyme complex prepared from a Penicillium mold. The principal enzyme involved is a pectic enzyme. The enzyme is added to the fresh juice which is then allowed to stand about 24 hr. to permit clearing by enzyme action. Pectin is hydrolyzed and precipitated as pectic acid. The enzyme is obtainable commercially under the name pectinol (see Kertez; also Marshall).

Apple juice so clarified may deposit a sediment after bottling unless pasteurized to destroy the enzyme. For further details, see Marshall, 1937.

BOTTLING OF FRUIT JUICES

Clear fruit juices are very attractive in glass containers, a fact which aids naturally in direct advertising to the consumer.

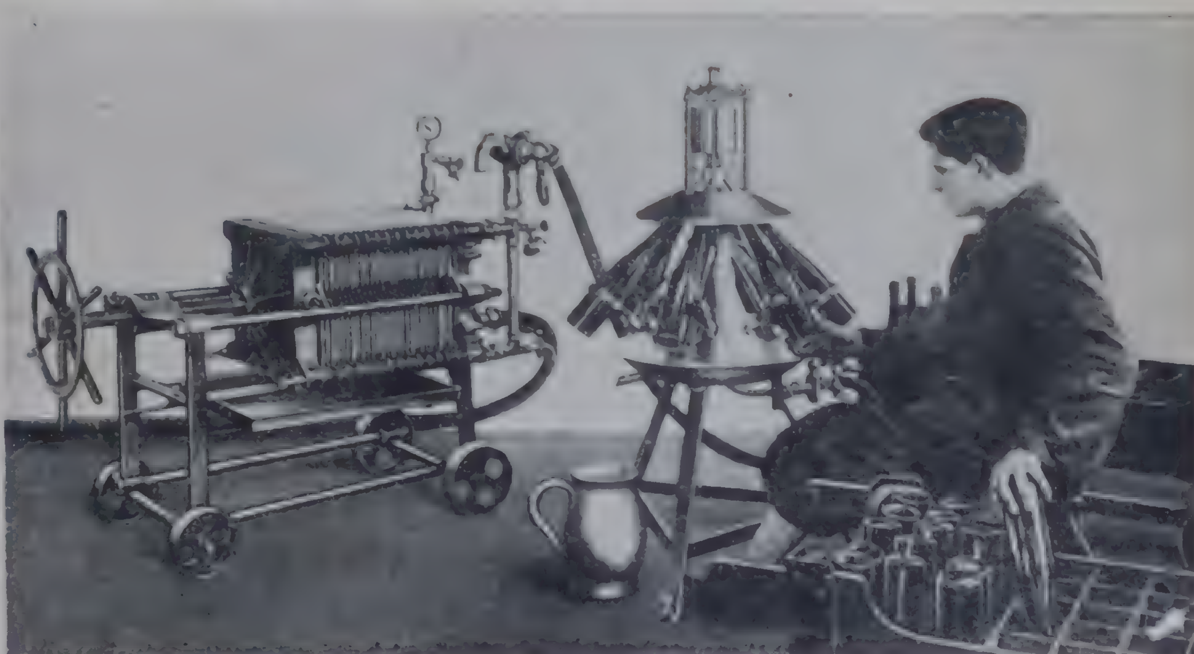

FIG. 54.—Filtering and bottling assembly. *(Courtesy The American Seitz Filter Co.)*

Preparation of the Bottles.—Bottles should be scrupulously clean and should be sterilized in live steam before use. Even a thoroughly rinsed bottle may contain a considerable number of mold spores and yeast cells. Large mechanical bottle soakers and washers are available which wash the bottles thoroughly in dilute lye solution and rinse them in water.

Caps.—The commonest and least expensive closure for bottles is the Crown cap, long used for bottled soda water, beer, and fruit juices. It consists of an outer metal disk, an inner cork disk which rests against the top of the bottle and makes the seal, of a shellacked paper disk between

the cork and metal disk, and usually a shellaced paper disk, known as a "spot," on the outer surface of the cork. This latter binds the metal disk and cork disk together. The cap is crimped to the bottle by compression in a Crown capping machine.

The Goldy cap is similar to the Crown cap but consists of two outer metal pieces, one of which is made of aluminum and can be torn from the bottle with the fingers. The White cap is held in place by friction or vacuum, a heavy soft-rubber gasket makes an airtight seal.

Corks are sometimes used, particularly for heavily carbonated juices, but they require the use of clamps during sterilization to prevent them from being forced from the bottles, are more expensive than caps, and are not so attractive in appearance.

Caps or corks should be sterilized in steam before use in order to kill mold spores.

Carbonation.—Bottled juices are usually more pleasing if carbonated. This may be accomplished in a continuous carbonator or in a bulk carbonator. In the latter the juice is carbonated at low carbon dioxide pressure in glass-lined tanks at about 30 to 32°F. In the former, the juice and carbon dioxide are mixed in a special chamber as the juice flows from the supply tank to the bottling machine.

Suitable carbonating and bottling equipment for carbonated juices can be had from any soda-water bottlers supply company. Stainless steel or other resistant metal must be used.

Experiments by the writer have shown that beer cans may be used successfully as containers for carbonated fruit juices.

Filling Machines.—Bottles are usually filled by automatic or semi-automatic machinery. For the small-scale bottling of fruit juices a hand-operated filler attached to a hose may be used.

Filling machines must be cleaned thoroughly after use in order to avoid development of mold and yeast during periods of idleness, and hose and other filling equipment should be thoroughly flushed with water and steamed before use.

GRAPE JUICE

The grape districts of New York, Ohio and Washington produce most of the bottled grape juice in the United States. The total annual production for the United States is estimated at about five million gallons.

Varieties of Grapes for Juice.—The Labrusca varieties are grown in New York and in the Middle West and the Vinifera varieties in California. The Labrusca varieties, such as the Concord, possess more acid and a more marked and characteristic flavor and aroma than the Vinifera varieties. Lack of distinctive character has made it difficult to market Vinifera juices.

Labrusca.—The Concord is the most popular of the eastern or labrusca varieties, and most of the bottled grape juice on the market is prepared from this variety. The Pierce Isabella is also excellent for juice. Dearing recommends it very highly and states that it produces a juice which is of more intense color and more easily clarified than Concord juice. He also recommends the Moore (Moore's Early), Catawba, Champion, Hartford, and Worden.

Vinifera.—Of the Vinifera (European) grapes grown on a commercial scale in California, the Muscat (a white raisin grape) is the only one possessing a very pronounced flavor, although the Semillon, Colombard, and Riesling have pleasing but delicate flavors. The Zinfandel, Petite Sirah, and Alicante Bouschet, all commercially grown Vinifera varieties, can be used satisfactorily with the Muscat to furnish the necessary color.

Muscadine.—In the Southern States the Scuppernong or Muscadine varieties, grapes of pronounced flavor, are grown extensively. Dearing has found the Thomas variety one of the best for juice because of its high acidity, flavor and sugar content. Others suitable for juice are the Latham, Mish, Carolina, James, Belle, Scuppernong, and Luola. The Thomas, Scuppernong, and Latham varieties produce white or yellow juices, and red juices are obtained from the James, Mish, and Luola.

Harvesting.—Labrusca varieties grown under eastern conditions should be harvested when they have reached full maturity and maximum flavor and color. The same rule applies to the Scuppernong varieties.

The Muscat should be harvested when its juice has attained 22 to 23° Balling (test made on an average sample by a Balling hydrometer at 60°F.). The red wine grapes to be blended with the Muscat should be gathered before full maturity, in order that the juices may be of higher acidity. This stage of maturity is 18 to 20° Balling for Petite Sirah, Alicante Bouschet, Barbera, and similar varieties and usually about 22° Balling for the Zinfandel variety. The last-named variety is often lacking in color if gathered below 22° Balling, and acidity is furnished in this case by gathering the second-crop grapes with the first crop.

Storage.—It is usually necessary to crush the grapes within 24 hr. after picking in order to avoid molding or fermentation. Hartmann and Tolman, however, recommend storing of crates of Concord grapes in a cool, well-ventilated place for 24 hr. or longer to permit mellowing and increase of the flavor and aroma of the grapes. In general it is advisable to crush as soon as possible after picking.

Boxes, crates, and baskets must be clean and should not be permitted to become impregnated with fermenting and moldy juice.

Crushing and Stemming.—Red grapes are crushed and stemmed in the manner described earlier in this chapter since the stems impart a harsh flavor, if heated with the crushed berries.

Muscat and other white grapes are not heated before pressing, and the stems may therefore be allowed to remain with the crushed grapes to aid in pressing.

Heating.—The color of red-juice grapes lies in the skins and is only slightly soluble in cold juice but dissolves quickly and readily in heated juice.

The crushed grapes are heated in steam-jacketed aluminum or glass-lined kettles, or the juice is drawn from the crushed grapes, is heated in a continuous pasteurizer, and is returned to the skins; the cycle being repeated until the desired temperature is attained.

It has been customary in commercial practice to heat the crushed fruit to 180 to 185°F., but Hartmann and Tolman point out that 150°F. should not be exceeded because of the extraction of an excessive amount of tannin from the seeds at higher temperatures. In experiments with Vinifera varieties in California the best results were obtained by heating the crushed grapes to 120 to 130°F. for 8 to 12 hr., although good results were obtained by heating to 160°F. for 5 min. only.

Pressing.—In the Concord grape juice district, rack and cloth presses are used. In California the basket press is used.

The press cloths act as a filter during pressing and eliminate much of the fine pulp otherwise obtained in the juice.

The total pressure applied is about 100 tons for a press using 48 by 48-in. racks and corresponds to about 87 lb. per square inch on the racks and cloths. The time allowed for pressing according to Hartmann and Tolman is about 85 min.

The pomace (press cake) is often broken up and pressed a second time.

The pomace from heated grapes is equal to about 15 per cent of the weight of the original grapes and contains about 60 per cent moisture and about 40 per cent solids. That from unheated grapes is usually about 20 per cent of the weight of the fresh grapes because pressing is less complete than with heated grapes.

The pomace is usually discarded, but it is suitable for stock food or for the manufacture of such by-products, as jelly, brandy, salad oil, tannin, and cream of tartar. The stems can be used as a source of tannin and tartaric acid but are usually discarded.

Sterilizing.—The juice is strained through a screen or cloth to remove coarse pulp and in most factories is then heated to 180 to 190°F. and transferred to large glass carboys or stoneware jugs.

Heating is for the purpose of pasteurizing; the lower the temperature at which this can be safely accomplished the better the quality of the juice will be, but the temperature must be high enough to destroy mold spores, normally not less than 175°F.

The continuous pasteurizer is preferable because it is more convenient and does not permit so great a drop in temperature between the pasteurizer and storage container as occurs with discontinuous pasteurizers.

Carboys.—The carboys should be thoroughly steamed before use and should be hot at the time of filling. They are filled and then sealed immediately with corks sterilized in hot paraffin, which prevents entrance of air and microorganisms during storage. The corks should be covered with melted paraffin after the carboys are corked.

Barrels.—In California 50-gal. barrels were formerly used as storage containers but are objectionable because they impart a woody taste to the juice, permit slow oxidation with loss of color and are difficult to seal against infection. Since juice remains hot in the barrels for 24 hr. or longer, the result is a loss of flavor and color.

Storage.—Storage is for the purpose of permitting separation of excess cream of tartar—acid potassium tartrate, $KH(C_4H_4O_6)$—and settling of suspended solids, much of which represent coagulated proteins. The temperature of storage should be low, about 32°F., in order to hasten separation of cream of tartar and minimize danger of fermentation.

Hartmann and Tolman have studied the changes in composition of Concord grape juice during storage, with the results given in Table 42.

TABLE 42.—CHANGES IN CHEMICAL COMPOSITION OF CONCORD JUICE DURING 4 MONTHS' STORAGE
(Per 100 cubic centimeter grams)
(*After Hartmann and Tolman*)

	Solids	Sugars (after inversion)	Non-sugars	Total acid as tartaric	Cream of tartar	Ash	Tannin and coloring matter
Before storage:							
Maximum	19.76	16.55	3.76	1.27	0.86	0.44	0.28
Minimum	16.99	13.38	3.06	0.98	0.64	0.34	0.15
Average	17.92	14.62	3.38	1.14	0.77	0.39	0.22
After storage:							
Maximum	19.18	16.30	3.07	1.10	0.63	0.32	0.22
Minimum	16.41	13.45	2.60	0.83	0.47	0.22	0.13
Average	17.39	14.52	2.87	1.01	0.53	0.27	0.18
Average loss	0.53	0.10	0.51	0.13	0.24	0.12	0.04

If the juice is not held under refrigeration, separation of the cream of tartar is slow, and at least 6 months' storage is usually necessary. At 32°F., 3 or 4 months' storage is usually sufficient.

Carboys with straight sides, because they permit more satisfactory settling of suspended solids, are better than flask-shaped containers.

Racking.—The settled juice is separated from the sediment by siphoning by means of a U-shaped tube attached to a flexible rubber hose. The U tube is inserted through the mouth of the bottle or barrel to a short distance above the sediment, and gentle suction is applied to siphon the juice into a suitable container.

The sediment, consisting largely of cream of tartar, is strained through cloth to separate it from the juice and may be dried for sale to cream of tartar factories.

Filtering and Fining.—In eastern factories the juice is usually only roughly filtered, whereas in California it was formerly usually fined with egg albumen or casein, as described earlier in this chapter and subsequently filtered. At present filtration is used.

Vinifera juices can be filtered very much more easily than Labrusca juices, since the latter are very rich in pectin and gums, hence viscous and difficult either to fine or filter. Pectic enzymes are very useful for treating such juices.

Bottling and Pasteurizing.—Grape juice is usually bottled as a still (not carbonated) juice, quart, pint, and 4-oz. bottles sealed with Crown caps being the usual containers. Bottles and caps must be clean and should be sterilized in steam before filling in order to destroy mold spores.

The bottled juice is pasteurized in water, usually for 30 min. at 175 to 180°F., and should be cooled after pasteurizing in order to check the deleterious effect of heat on the color and flavor of the juice.

Quick Process for Bottled Juice.—It is possible to freeze fresh juice to a mushy mass of ice crystals and syrup by 24 hours' storage at 0 to 15°F. This treatment causes immediate separation of excess cream of tartar, which can be removed after allowing the frozen juice to melt. The juice can then be filtered and bottled. The entire process requires about 48 hr. from crushing to bottling. Its use would greatly reduce the storage space and containers now employed in the sedimentation of grape juice.

Canning of Grape Juice.—Recently interest has revived in the canning of grape juice. As a result of experiments conducted by the writer, Lyman Cash, and Ralph Celmer in 1935 and 1936, the following new information has been secured.

Juices, both white and red, in unlacquered tin cans soon lost their fresh flavor, aroma, and color and acquired a disagreeable "tinny" flavor. Juices in lacquered, ordinary coke-tin cans attacked the plate rather rapidly, whereas those in double-lacquered (reenameled), Type L plate remained in good condition for more than a year without appreciable loss in vacuum and without perforation of the plate. Beer cans lined with "wax" and sealed with crown caps proved satisfactory for both still and carbonated juices. Deaeration of the juice before canning

improved keeping quality. Enzymic clarification with pectinol or with clarase was rapid and satisfactory. Fining with bentonite at 140 to 180°F. also gave excellent clarification. A blend of Muscat and Petite Sirah, or Muscat and Zinfandel, juices was satisfactory but not so desirable as Pierce Isabella juice or a blend of this juice with a red vinifera variety. Muscat juice, canned as such as a white juice, was very pleasing in quality and should have commercial possibilities. Acidification of vinifera juice to about 0.85 gram total acidity per 100 cc. was found desirable.

The following procedure is suggested for red vinifera juice: Pick Muscat grapes at about 22 to 23° Balling. Crush and press. Pick a red juice variety, such as Petite Sirah, Alicante Bouschet, Zinfandel, or Carignane, grown in a coastal county at 19 to 20° Balling. Crush and stem. Heat at 160°F. for 5 min. Press hot. Cool at once. Mix equal volumes of the two juices. Deaerate by treating under 27 to 29 in. vacuum at 80 to 100°F. for 20 to 30 minutes. Flash pasteurize at 180°F. and cool to below 120°F. Add the amount of a 5 per cent water suspension of bentonite—found best by small-scale trial. Mix well. Acidify with citric acid to 0.85 per cent total acid. Let settle several hours. Rack and filter. Heat to 140°F. Fill reenameled Type L cans with the hot juice. Seal in vacuum. Process at 140°F. for 20 min. Cool thoroughly.

For white Muscat juice proceed essentially as above, omitting addition of red juice.

For Pierce Isabella, Concord, or other red Labrusca or red Muscadine juice, proceed as directed above except that no Muscat juice is added.

An alternative procedure for the canning of grape juice is as follows. Extract the juices as previously directed. Flash pasteurize, and cool to 80 to 60°F. Add pectinol or clarase in amount found by small-scale trial to be best (usually about 1:5,000). Let stand until clotting occurs. Rack. Filter. Heat to 140°F. Can hot in reenameled Type L cans. Seal under vacuum. Process at 140°F. for 30 min. Cool thoroughly.

Carbonating Grape Juice.—Grape juice can be carbonated in any of the standard types of carbonating machines. At the University of California the juice is placed in a heavy steel cylinder lined with "glass enamel" and is agitated mechanically at 32 to 36°F. in the presence of carbon dioxide gas under 20 to 30 lb. pressure. Thirty pounds pressure gives an agreeable degree of carbonating at 36°F.

The juice can also be carbonated by allowing it to flow downward against a stream of carbon dioxide in a narrow tube filled with glass beads, or by chilling the juice to 28 to 32°F. and passing a slow stream of carbon dioxide through it.

Juice carbonated at 30 lb. or greater pressure at room temperature can be pasteurized at 140 to 150°F. without danger of subsequent molding, whereas noncarbonated juice must be pasteurized at 175°F. The lower temperature of pasteurization of carbonated juice results in much less injury to flavor and color than occurs at 175°F. or above. The carbonated juice may also be canned in beer cans and pasteurized 30 min. at 140°F.

Another method of preparing carbonated beverages consists in concentrating the juice to a syrup, followed by mixing the syrup and carbonated water in the bottle with standard soda-water bottling equipment.

Alcohol in Unfermented Grape Juice.—Hartmann and Tolman found by the analysis of 104 samples of Concord juice that 44 per cent of the samples contained less than 0.1 per cent of alcohol; 77 per cent contained 0.2 per cent or less; and 90 per cent showed 0.4 per cent or less of alcohol by volume. The remaining 10 per cent contained from 0.4 to 1.07 per cent alcohol by volume.

They found that freshly picked grapes contained very little alcohol and that most of the alcohol was formed by yeast during transportation, storage before crushing, and during crushing and pressing.

APPLE JUICE

Unfermented apple juice (sweet cider) is one of the most popular fruit juices sold in the United States, most of this juice being consumed fresh, directly after pressing, or from barrels in which it is preserved with benzoate of soda. Benzoated cider is often of very poor quality and usually the flavor of benzoate is evident. The sale of cider preserved in this manner is, in the writer's estimation, the principal obstacle to expansion of the sweet cider industry.

Varieties of Apples for Juice.—Apple juice should possess a rich apple flavor and should be tart. The Winesap, Yellow Newton Pippin, Roxbury, Spitzenberg, and Northern Spy are examples of good cider apples obtainable in commercial quantities.

Gore has compared the quality of juices from a number of leading apple varieties after pasteurization and storage with the results given in Table 43.

Gore has also studied the effect of composition of the juice and its desirability as a beverage, as shown in Table 43.

He concluded that apple juice to be most palatable to the average consumer should contain about 12 per cent or more of total solids and 0.5 per cent or more of total acid (as malic).

Experiments by R. Celmer and the writer in 1936 showed that, of Californian commercial varieties, the Gravenstein gave the most palatable canned juice. It was distinctly superior to the Newton Pippin. Wine-

sap and Spitzenberg apples from Washington State and Stayman from Pennsylvania gave excellent canned and bottled juices. The apples from the Pacific northwest are high in total acidity, *i.e.*, tart in taste, which is a desirable characteristic.

In addition to the proper proportions and concentrations of acid and sugar, the juice must possess a distinctive and agreeable flavor. For example, the Ben Davis, while conforming in composition to Gore's requirements, yielded a juice of poor flavor and quality, because of its lack of distinctive apple flavor. The Yellow Newton, Winesap, Northern Spy, Baldwin, Roxbury, and Kentucky Red all gave satisfactory juices.

TABLE 43.—COMPARATIVE QUALITIES OF JUICES FROM SEVERAL VARIETIES OF COMMERCIALLY GROWN APPLES
(*After Gore*)

Variety	Source	Quality of sterilized juice
Yellow Newton (syn. Albemarle Pippin)	Waynesboro, Va.	Juice very palatable; distinguished from the fresh only by the slight cooked taste and a little bleaching or lightening of color.
Ben Davis	Waynesboro, Va.	Quite unpalatable; lacking in distinctive apple flavor.
Winesap	Waynesboro, Va.	Very palatable; the fruity flavor somewhat impaired by sterilizing; slight bleaching noticeable; very little cooked taste.
Tolman (syn Tolman Sweet)	Halls Corners, N. Y.	A very dark-colored, thick juice; very sweet and insipid.
Northern Spy	Halls Corners, N. Y.	Very fine in flavor; a fine rich juice, showing slight bleaching and hardly detectable cooked flavor.
Baldwin	Halls Corners, N. Y.	High in quality, very palatable; slightly bleached and with slight cooked flavor.
Roxbury (syn. Roxbury Russet)	Halls Corners, N. Y.	A heavy, rich juice, very palatable; slightly bleached and with very slight cooked flavor.

Preparation for Crushing.—Although cider is usually considered a by-product and a means of utilizing culls, the raw material should be sound, free from rot, worms, and fermentation. Apples to be used for cider should in all cases be thoroughly washed before crushing, because even under the best conditions they will carry considerable dust and are frequently contaminated with juice or pulp from spoiled fruit. The apples may be soaked by conveying them through a long tank of running

water and the loosened dirt may be effectively removed by sprays. Undoubtedly a rotary tomato washer would be ideal for the washing of apples. Merely washing the apples in running water a short time as is done in some factories does not cleanse them effectively.

Sorting is even more important than washing in order that rotten and wormy fruit shall be removed.

The federal food and drug regulations prohibit the marketing of apple juice or any other food containing more than 0.018 grain of lead or 0.01 grain of arsenic as the trioxide per pound. As all commercially grown

TABLE 44.—COMPOSITION OF UNFERMENTED APPLE JUICE FROM DIFFERENT VARIETIES OF APPLES
(*After Gore*)

Variety	Total solids, per cent	Acid as malic, per cent	Reducing sugar, per cent	Total sugar, per cent
Yellow Newton (syn. Albemarle Pippin)	12.35	0.53	9.15	11.58
Ben Davis	12.05	0.48	7.86	10.05
Winesap	11.64	0.46	9.06	10.02
Tolman (syn. Tolman Sweet)	15.63	0.13	9.92	13.95
Northern Spy	14.90	0.61	8.52	12.82
Baldwin	14.31	0.63	7.33	12.22
Roxbury (syn. Roxbury Russet)	16.86	0.70	7.46	13.81

apples are heavily sprayed with lead arsenate, they usually carry, in the orchard, a heavy residue of this spray. It cannot be removed by simple washing. Robinson of Oregon Agricultural College, who has studied this problem extensively, recommends immersion and agitation of the apples in an approximately 1.5 per cent hydrochloric acid solution followed by rinsing in water. Apple juice should be analyzed for lead and arsenic content to ensure its compliance with the law (for further details see *Oregon Agricultural Experiment Station, Bulletin* 341).

Grating and Pressing.—The construction and operation of apple hammer mills, graters, and presses have been discussed earlier in this chapter.

Apple tissue is firm and tough, and the cells possess heavy walls; consequently crushing or grating and pressing must be thorough in order to obtain a high yield of juice. Crushing too finely, however, causes the pulp to be too soft to press without danger of bursting the press cloths. Pieces ¼ to ⅛ in. thick are satisfactory. The rack and cloth rather than the basket press is best for apples because of the pulpy nature of the fruit. The usual pressure applied to a press using racks 55 in. square is about 235 tons, or about 150 lb. per square inch.

The yield of juice from one pressing should be 160 gal. or more per ton. The pomace (press cake) may be broken up in a pomace picker (similar to an apple-grating machine) and pressed a second time, but the second pressing of juice is of very dark color, of poorer flavor than the first pressing and is more suitable for vinegar than for sweet cider.

Clearing of Unfermented Cider.—It is frequently possible to clarify sweet cider by filtration directly after pressing, without preliminary heating to coagulate proteins, although it is usually desirable to pasteurize it before filtration, by heating to 165°F. and cooling at once. The juice can be filtered as described for grape juice.

Filter presses fitted with aluminum-bronze or stainless-steel forms are used in some apple-cider factories, infusorial earth being mixed with the juice before filtration.

Cider may be clarified very successfully by pectic enzymes, as described by Kertez and others, or by the addition of 1,000 to 1,500 grams of Spanish clay or bentonite per hectoliter, as described earlier in this chapter (see Kertez and Carpenter references on enzyme use).

Carbonating.—Cider is greatly improved for the average consumer by carbonating, and much of the bottled cider now on the market is lightly carbonated, *i.e.*, at 15 to 20 lb. pressure per square inch.

During the Prohibition era some breweries were converted into cider factories in some apple-producing localities, particularly in the Pacific northwest, and the carbonating, bottling, and pasteurizing equipment formerly used in these establishments for beer was used successfully for cider.

Bottling and Pasteurizing.—These operations are accomplished as described for grape juice, although still (noncarbonated) cider usually is pasteurized at 165 to 170°F. (as compared with 175°F. for grape juice). Carbonated cider can be pasteurized at 140°F.

Canning Cider.—The writer believes that there exists a very large potential market for canned apple juice of good quality. As a result of experiments conducted by Ralph Celmer and the writer the following procedure is suggested: Sort and wash in dilute acid to remove spray residue. Crush in a hammer mill. Press. Strain. Deaerate under 27 to 29 in. vacuum 15 to 20 min. to remove dissolved oxygen. Flash pasteurize at 180°F. Cool to about 120°F. Add bentonite and mix. Settle. Rack. Roughly filter. Heat to 165°F. in a continuous pasteurizer. Can in reenameled, Type L cans. Seal hot. Invert cans for 2 to 3 min. Cool thoroughly. Instead of bentonite clarification, a pectic enzyme or rough clarification by a special centrifuge can be used.

Distribution under Cold Storage.—In experiments made at the University of California unpasteurized cider in sealed cans retained the qualities of the fresh juice for more than 24 months when stored at 0 to

15°F. At 32°F. fermentation occurred. When stored in open containers at 0 to 15°F., the juice acquired a disagreeable musty flavor, caused by the absorption of odors from the atmosphere of the cold room.

LOGANBERRY JUICE

The preparation of loganberry juice is an important industry of the Pacific northwest, where most of the juice is now canned in fruit canneries. The canned juice is proving popular.

When the berries are fully mature and have attained their maximum color and sugar content, they are gathered in shallow trays. The fruit is soft and develops fermentation quickly after harvesting, and for this reason it must be crushed within a few hours.

Juice Extraction.—Various methods of extracting the juice can be used, but the following is recommended. The berries are crushed in a bronze crusher and pressed in a rack and cloth cider press. In most cases the berries are heated to 160°F. before pressing, to increase the yield and to obtain a juice of more intense color. Juice from unheated fruit contains less pectin and is therefore more easily filtered.

If the berries have not been heated before pressing, the juice is heated after pressing, to pasteurize it and to coagulate heat-precipitable proteins. Stainless-steel or glass-lined equipment should be used in heating berries and berry juices. Aluminum corrodes rapidly and most other metals, including tin, injure the color.

Filtration.—Filter presses or pulp filters may be used for filtering the juice. Because of its high content of gums and pectin, it is difficult to filter.

It is not necessary to place the juice in cold storage to permit settling before filtration. It is feasible to filter the juice satisfactorily after 24 hours' settling at room temperature following preliminary pasteurization at 160 to 165°F. to coagulate proteins. Clarification with pectinol enzyme greatly aids filtration.

Addition of Sugar.—Unsweetened loganberry juice, after bottling or canning and pasteurizing, usually develops a disagreeable astringent flavor and loses most of its color, but the addition of a moderate amount of sugar prevents these undesirable changes. The added sugar gives a more pleasing beverage than the unsweetened juice, but sugar in excess of 50 per cent often causes the juice to form a jelly.

The sweetened filtered juice can be canned or bottled and pasteurized as described for other juices. Before canning it is usually diluted with an equal volume of water and sweetened to taste (about 12 to 14° Balling) with sugar. Reenameled, Type L cans are used.

The yield of freshly pressed juice is 160 to 180 gal. per ton, and twice these amounts of diluted juice. The juice may be pasteurized into the cans at 175 to 180°F., or pasteurized in the cans.

Carbonating.—An excellent carbonated beverage for bottling purposes can be made from sweetened loganberry juice. One and one-half ounces of sweetened juice of 50° Balling is added to 8-oz. soda-water bottles and carbonated water at 30 to 50 lb. pressure is added to fill the bottle which is then crown capped and pasteurized at 150°F. for 30 min.

OTHER BERRY JUICES

Other berries also yield palatable beverages, particularly if sweetened and diluted with carbonated water.

Blackberry Juice.—Blackberry juice can be prepared as described for loganberry juice but the Balling degree of the juice should be increased to 30° by the addition of cane sugar, to prevent deterioration of flavor and color. Unsweetened juice pasteurized and stored at room temperature loses most of its color and flavor. Because of its intense color it is very useful in fruit punches and sherbets.

Gore reports yields of 66.9 to 69.6 per cent of juice from unheated blackberries and 74.4 to 80.9 per cent from blackberries heated before pressing. The sweetened juice is diluted before serving.

Youngberry Juice.—The Youngberry or Young Blackberry is grown in considerable quantity on the Pacific coast. It is a large berry of pronounced flavor and moderate acidity and is popular as a dessert fruit. In experiments in this laboratory by R. Celmer, a very pleasing canned diluted juice was prepared as described for canned blackberry juice.

This berry is adaptable to culture, not only in Oregon, California, and Washington, but in many sections of the Southern States. It could well become an important juice fruit.

Boysenberry Juice.—This new variety yields an excellent juice. It is best if sweetened to 35° Brix before bottling; to be diluted before serving.

Raspberry Juice.—If acidified slightly with citric acid, raspberry juice of satisfactory quality may be prepared and canned or bottled as described for blackberry juice. It is lighter in color and of lower acidity than loganberry juice, but it is very rich in flavor and aroma.

CITRUS JUICES

Until relatively recently all attempts to pack commercially a satisfactory canned or bottled orange or lemon juice were unsuccessful because of undesirable changes in flavor and odor during storage. With development of the technique devised by Joslyn and Marsh of this laboratory and adoption of a special enamel, the canning of orange juice has become an important industry in California.

For a number of years the canning of grapefruit juice has been conducted commercially in Florida, Puerto Rico, and Texas.

Canning of Orange Juice.—In California the Valencia variety is preferred to the other important commercial variety, the Navel, since it retains its flavor and aroma more satisfactorily.

The oranges must be well ripened; otherwise, the juice will develop a bitter taste.

As stated earlier in this chapter, one of several methods may be used to extract the juice. The usual procedure consists in sorting the fruit carefully on a broad belt, washing it thoroughly, cutting it in half mechanically, and reaming out the juice and pulp on rapidly revolving bronze

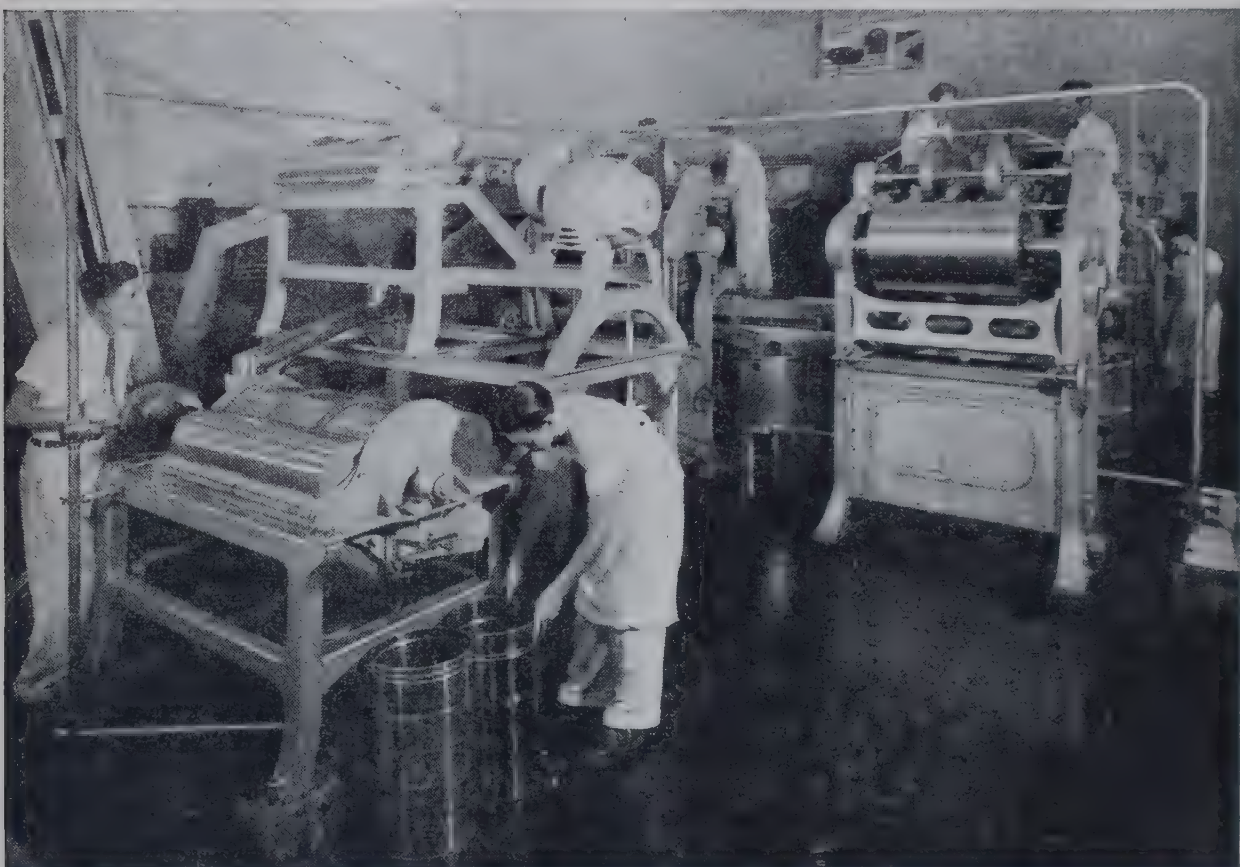

FIG. 55.—Extracting and straining orange juice. (*Courtesy F. W. Bireley Co.*)

cones of suitable size. In some plants men apply the halved fruit to the cones by hand; in others this operation is done by a very ingenious automatic machine. The juice is strained or passed through a tomato finisher in order to remove coarse particles and seeds.

In most plants it is then subjected to a high vacuum in a glass-lined or stainless-steel tank to remove oxygen. It is next flash pasteurized at about 190°F., cooled to 170 to 175°F., filled into "citrus enamel" cans at this temperature, sealed and cooled in sprays of water quickly to slightly above room temperature. Cooling is accomplished most rapidly by rolling the cans along a conveyer beneath heavy sprays of water. The agitation due to rolling brings the hot juice to the walls of the can, where heat interchange with the cooling water is facilitated. The latent heat of

vaporization of water from the can surfaces greatly increases the cooling power and rate.

Various modifications of the preparatory and canning procedures are used. In some canneries vacuum treatment, or flash pasteurization, or both, are omitted. In at least one plant the vacuum is released with nitrogen instead of with air. In some plants the juice is pasteurized in the cans after sealing.

Orange juice prepared by vacuum treatment and flash pasteurization is also packed in bottles.

At one time some orange juice was prepared by crushing and pressing the whole fruit, separating as much of the essential oil from the juice as possible by centrifugal separators, and then proceeding as previously described. It is now believed, however, that essential oil from the rind should be excluded insofar as possible, since the terpenes change in flavor rather rapidly and spoil the flavor of the product. For this reason the juice is prepared as free of essential oil as possible.

Orange Beverage Bases.—Lightly sweetened orange juice is concentrated *in vacuo* in stainless-steel vacuum pans to a heavy syrup for use as a base for carbonated and still beverages. One such still beverage is at present distributed extensively in milk bottles for sale in soda fountains and for use in the home. It is made by diluting the sweetened concentrate to drinking strength. Carbonated bottled beverages made from such concentrates are also popular. The syrups and the carbonated beverages are preserved with sodium benzoate.

Frozen Orange Juice.—Some orange juice is preserved by freezing in enamel-lined cans for use by ice-cream producers, hospitals, steamships, and other large users of fruit juices. Attempts to distribute frozen orange juice in the retail trade or direct to the home have not been very successful, although the product is satisfactory. Apparently housewives prefer to use the fresh oranges or the canned juice, as the cost for an equivalent amount of juice is considerably less than that of the juice distributed in the frozen state (for further discussion of frozen juices see Chap. XXI).

Lemon Juice.—Lemon juice deteriorates in flavor even more rapidly than orange juice. Nevertheless, there is at present a moderate demand for canned lemon juice prepared and canned by the procedure described for the canning of orange juice. Within a few weeks after canning the lemon juice develops a "terpeny" or stale lemon taste and odor, yet it is satisfactory for use in mixed drinks and appears to find sale to bars, restaurants, clubs, etc.

Some lemon juice is bottled also. It may be prepared by reaming the fruit, screening out seeds and coarse pulp, vacuumizing to remove oxygen, flash pasteurizing, bottling at 175°F., sealing hot, and cooling. Or it may

be cooled after flash pasteurizing, bottled warm, sealed, and pasteurized in the bottle at 165°F.

Lime Juice.—Lime juice, like lemon juice, rapidly develops a "stale" taste after bottling or canning, although this off flavor is much less

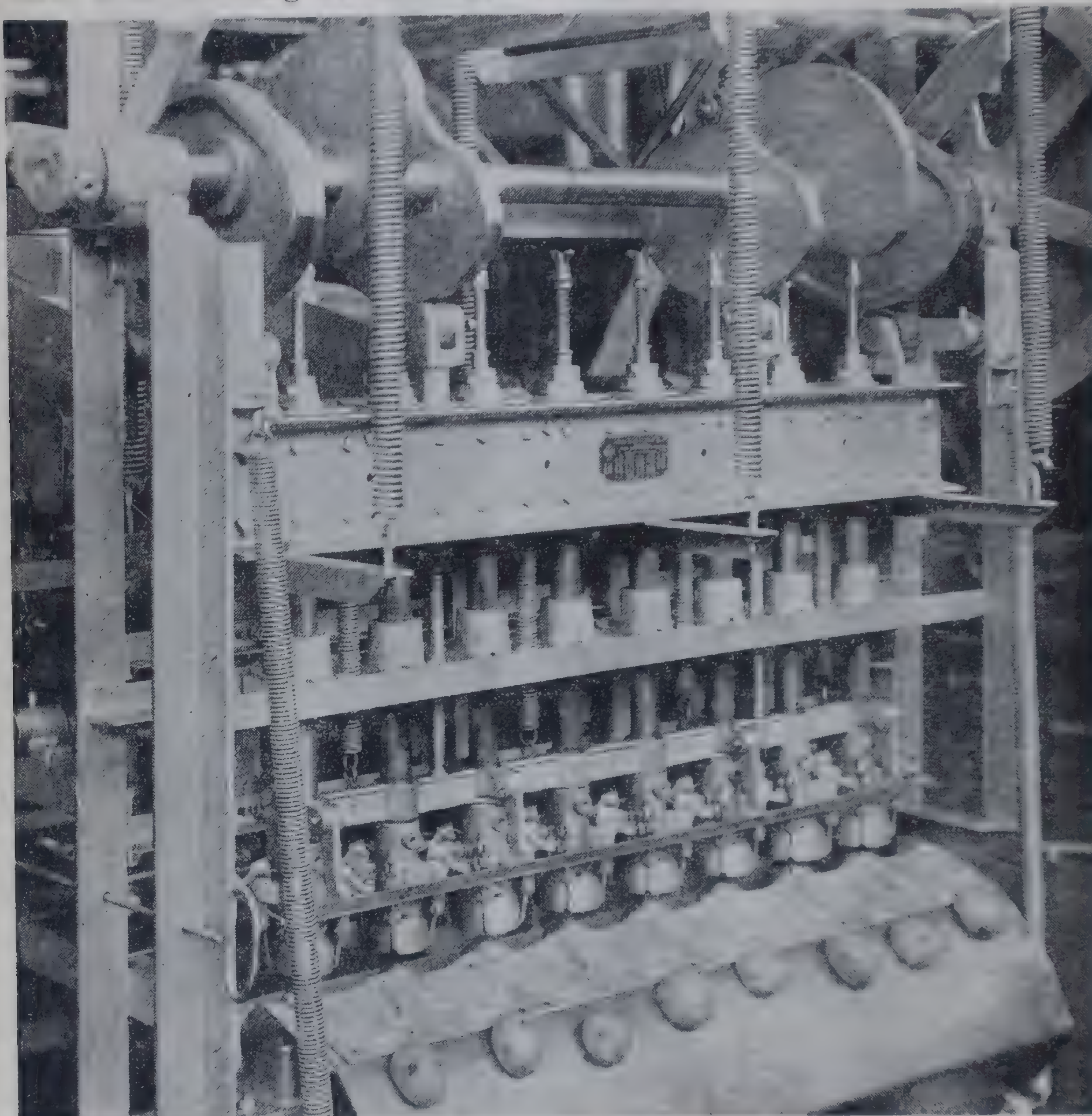

Fig. 56.—Automatic orange juice extractor. (*Courtesy the Food Machinery Corp. and Florida Citrus Machinery Corp.*)

objectionable in lime than in lemon juice. Considerable lime juice is filtered brilliantly clear and preserved in bottles with sulfur dioxide.

It possesses a richer flavor, however, if bottled in the cloudy condition. The procedure outlined above for lemon juice may be used successfully.

Grapefruit Juice.—The canning of grapefruit juice for a number of years has been a well-established industry. Most of the commercial product is packed in cans. Those lined with "citrus enamel" should be used in order to minimize development of a tinny flavor. In the early

days of the industry considerable loss was encountered from hydrogen swelling by reaction of the acid of the juice with the tin plate. With improvement in tin plate and in preparation of the juice such losses are now relatively slight.

The juice is canned either in its natural state or slightly sweetened with cane sugar, depending upon the composition of the fruit used.

In experiments made in this laboratory, it has been found that fresh flavor and aroma are retained in greater degree if the procedure outlined for the canning of orange juice is used instead of canning without vacuumizing or flash pasteurizing. The recommended procedure is then, briefly, as follows: Use well ripened, sweet fruit. Cut in half. Remove juice by reaming, avoiding expressing essential oil from the rinds. Strain. Treat under a high vacuum (27 to 29 in.) for 20 to 30 min. to remove dissolved and occluded oxygen, or use continuous vacuumizer. Flash pasteurize at 190°F. for about 1 to 2 min. Cool to 175°F. Can at this temperature in citrus enameled cans. Seal hot. Cool thoroughly under sprays of water as described for orange juice.

It is recognized, however, that grapefruit juice is much more stable in flavor than orange, lemon, and lime juices. Consequently it withstands more severe treatment and retains its flavor more satisfactorily after canning or bottling.

Bottling may be conducted as previously described for orange juice.

Pineapple Juice.—Canned pineapple juice is now second only to canned tomato juice in respect to volume of pack. It is an excellent juice for canning since it retains its fresh flavor and aroma remarkably well and is of such acidity and sugar content that it is properly balanced in flavor for use as a breakfast beverage.

The fruit used should be well matured but not so ripe that the acidity has become too low or the juice too gummy. Juice from the rind is harsh; therefore, the fruit should be peeled as for canning, *e.g.*, by Ginaca machine. The juice can be recovered by coarsely shredding the fruit and pressing in a continuous, screw press (expeller). It may then be strained, vacuumized, flash pasteurized, and canned as outlined for orange juice except that plain tin cans are used.

Another satisfactory procedure consists in expressing the juice, clearing it by centrifugal clarifier, roughly filtering or not as desired, canning in plain tin cans, sealing under vacuum and pasteurizing at about 135°F. for a long enough period—determined by test—to destroy yeasts, and cooling.

A brilliantly clear juice is not desired; on the other hand a muddy juice that gives a bulky sediment is also undesirable. Sand filtration, thorough straining through fine screens, or centrifugal clarification is

normally sufficient. A combination of centrifugal clarification and rough filtration may be used also.

Several types of juice extractors are in use. The Schwartz juice extractors are very powerful, vertical, continuous presses giving a high yield of juice. A revolving member breaks the fruit into fine fragments against a serrated surface; after which the juice and pulp are separated by a fine screen. The American Utensil Company's pineapple juice extractor, similar in design to its well-known tomato-juice extractor, also is in use. The Sprague Sells extractor is also satisfactory and is in use.

In other words, methods vary in different plants and are undergoing change and improvement. The pineapple juice industry in this respect is similar to the orange-juice canning industry. The processes in both cases are far from being static. Problems are arising continually and in both cases research is indicating methods of improving process and product. Consequently the procedures given in this chapter are very apt to be greatly modified in the next few years.

Tomato Juice.—As tomato juice has become an important tomato product and as much of the equipment used for preparing other tomato products is also employed in producing tomato juice, the preparation and preservation of this juice are presented in Chap. XIX.

Pomegranate Juice.—This is a subtropical fruit found in California and Arizona. The rind of this fruit contains a very large amount of excessively "puckery" tannin which enters the juice and renders it undrinkable if the whole fruit is crushed and pressed in the manner employed with apples. If, however, the uncrushed whole fruit is placed in a basket press and pressed under moderate pressure a juice of pleasing flavor and attractive purplish red color is secured.

The juice is easily clarified by heating in a flash pasteurizer to 175 to 180°F., cooling at once, settling 24 hr., racking, and filtering. It may then be bottled and pasteurized as previously described for grape juice.

If the juice should have an excess of dissolved tannin, the tannin content should be determined by titration with potassium permanganate as directed in the "Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists," and before flash pasteurization there should be added sufficient 1 per cent gelatin solution to precipitate about two-thirds of the tannin. One part by weight of gelatin is roughly equivalent to one of tannin. A preliminary test with about 1,000 cc. of the juice should first be made; as addition of an excess of gelatin will cause the juice to become permanently cloudy and extremely difficult to filter.

Passion Fruit Juice.—In Australia this fruit is produced in considerable quantity for preparation of juice. It grows on a vine similar in

growing habits, but of course not botanically, to the hop vine. The fruit is cucumber-shaped and contains many seeds. By a combination of crushing, pressing, and screening, a cloudy juice may be obtained. It is very aromatic and mildly acid. Sugar should be added to bring the Balling to approximately 25°. The juice may then be canned or bottled and pasteurized in the usual manner at 140 to 150°F. in cans, or 175°F. in bottles. This juice is very useful in preparing mixed fruit punches and mixed alcoholic drinks.

Apricot Juice.—This juice has become rather popular. Its production was initiated as a result of experiments made in this laboratory by A. Shallah and the writer.

The present commercial procedure consists in pitting the fruit by machine, grinding and sieving to a purée, adding sugar and water or 15° Brix cane-sugar syrup equal to volume of purée, heating, canning hot, sealing, and processing. In some canneries a hammer-mill type disintegrator is used to make the purée. In others a tomato-juice extractor is used.

In our experiments we used the following procedure: The apricots (thoroughly ripe) were pitted, steamed until soft, sieved in an American Utensil Co. tomato-juice machine, and mixed with an equal volume of 15° Brix syrup. The mixture was heated to 180 to 185°F., canned hot, sealed, processed at 212°F. 20 min. in No. 1 tall cans, and cooled. This procedure retains vitamin C, whereas cold sieving of the fresh, raw fruit may lose it.

Peach and Pear Juices.—The fruit is pitted, or cored and peeled. It is then steamed until soft and canned as described for apricot juice.

Plum Juice.—Ripe plums are washed, steamed soft, pulped in a tomato cyclone, finished in a tomato finisher, mixed with 15° Brix syrup, and canned as above. Enamel-lined (berry-enamel, Type L) cans should be used for red plum juice.

CARBONATED FRUIT BEVERAGES

Many of the so-called "fruit" soda waters on the market are prepared from artificially colored and flavored syrups. While many of these beverages are palatable, they contain in most instances little or no fruit juice. Investigations at the University of California have proved that fruit juices can be readily converted into syrups suitable for the use of soda-water bottlers and soda fountains and that the consuming public prefers these beverages to those produced from the artificially colored and flavored syrups.

Preparation of the Syrups.—A detailed discussion of the preparation of fruit syrups will be found in Chap. XVI.

The juice is obtained from the fruit in the manner best suited to the fruit in question and as described earlier in the present chapter.

Berry juices, pomegranate juice, and most citrus juices are converted into syrups by the addition of sugar; grape juice, apple juice, and pineapple juice are concentrated by freezing and centrifuging or by vacuum pan concentration, as described in Chap. XVI.

The syrups are preserved by pasteurization, by sodium benzoate, or by cold storage.

Berry syrups and pomegranate syrup are made to about 35 to 45° Balling, grape juice is concentrated to about 60° Balling, and other juices, except orange, to about 55° Balling. Orange juice is slightly sweetened with cane sugar and concentrated to about 72 to 75° Balling.

Carbonating and Bottling.—In using the syrup, about 1½ fl. oz. of the syrup are added to each soda-water bottle of 7-ounce size. Carbonated water at 30 to 40 lb. pressure is added to fill the bottles. The bottles are sealed with crown caps at once and are then placed in a pasteurizer and heated to 150°F. for 30 min.

Standard soda-water bottling equipment can be used for carbonating, bottling, and pasteurizing.

The cost of the fruit and sugar for the syrups used in a 7-oz. bottle of the carbonated beverage will in most cases not exceed 1½ cents. The beverages can be sold retail for not to exceed 10 cents per 7-oz. bottle and with fair profit to all concerned in the manufacture and distribution of the beverage.

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CHAPTER XVI

FRUIT AND VEGETABLE SYRUPS

Maple, sorghum, and cane syrups have long been standard food products. Before the discovery of America the Indians used the concentrated sap of the maple as a food. The early white settlers quickly adopted the product and improved upon the crude methods of manufacture used by the aborigines.

Later, sorghum was planted in the Middle West and cane in the South to supply raw material for syrup. The manufacture of sorghum and cane syrups has become an important industry.

Fruit syrups are becoming popular for the preparation of beverages and soda-fountain specialties and in certain cases provide an outlet for the lower grades of fruits. Starchy vegetables, particularly sweet potatoes, have been investigated successfully as sources of syrup.

Types of Syrups.—There are a number of different types of syrups produced commercially.

Table Syrups.—Most table syrups are made by dissolving cane sugar or glucose, or a combination of the two, in water and flavoring the solution with an imitation maple flavor, vanilla, or other suitable flavoring. In some sections of the United States, particularly in the South and Middle West, the sap of sorghum cane and sugar cane is concentrated to a heavy syrup for table use.

Cooking Syrups.—Molasses is a by-product of the sugar industry and is the mother syrup remaining after the crystallization of the sugar. It consists largely of a concentrated solution of invert sugar and dissolved solids which are uncrystallizable. However, concentrated pure cane juice is also often called molasses. It is edible and is used extensively in cooking, particularly in the preparation of gingerbread, cookies, imitation brown bread, etc. Beet molasses is not edible.

"Sorghum molasses" is really a syrup rather than a true molasses because it contains the whole cane juice from which sugar has not been crystallized.

Fountain and Bottling Syrups.—Under this heading is listed a great variety of syrups, most of which are wholly or in part synthetic preparations. Examples of the synthetic syrups are ginger ale syrup and similar syrups, and imitation fruit flavors, as orange, lemon, lime, cherry, and berry syrups. It is not our purpose to describe the manufacture of these synthetic preparations.

Real fruit syrups are now coming into greater favor. These represent in most cases fruit juices sweetened with cane sugar and preserved by pasteurizing or by sodium benzoate.

METHODS OF CONCENTRATION AT ATMOSPHERIC PRESSURE

Many syrups are prepared by concentrating a juice or sap or saccharified extract to a syrupy consistency. The method of concentration varies considerably, according to the character of the raw material and the size of the plant.

Open Concentrators.—The simplest form of concentrator is an open kettle, which may be heated by direct flame, by a steam jacket, or by a steam coil.

Direct-fired Kettle.—This may consist of a cast-iron kettle placed over a firebox in which wood or other fuel is burned. Syrup produced in such an outfit is usually severely caramelized and darkened by overheating and by iron salts formed by the action of the juice on the iron.

Sorghum Pan.—A great improvement upon the direct-fired cast-iron kettle is the so-called "sorghum pan" used for maple, cane, and sorghum syrups. This is a shallow rectangular pan (not more than 4 to 6 in. deep) made of copper, tin-lined copper, galvanized iron, or very heavy tin plate, and it rests on a firebox. It is divided crosswise into sections with thin strips of metal, and the sections are connected, giving in effect a zigzag path which the juice follows during the boiling process. Galvanized iron is not desirable because the zinc coating is attacked by the juice. The fresh sap or juice enters the firing end of the pan, and the finished syrup is drawn off at the chimney end. The operation is continuous.

The pans vary in length from about 6 to 8 to about 15 ft., and can be lifted from the firebox to permit cleaning.

In using the pan the bottom is first covered with water, and the juice to be concentrated is then allowed to run into the upper end of the pan to displace the water. As it flows through the zigzag channel of the pan it is concentrated by boiling. The rate of flow is so adjusted that syrup of the required density flows continuously from the outlet. A shallow layer of juice in the pan permits more rapid concentration than does a deep layer and for this reason gives a syrup of lighter color and with less scorched flavor.

During boiling the syrup must be skimmed frequently to remove coagulated protein, etc.

Some syrup manufacturers use two pans. In the first the juice is partially concentrated to cause clarification. The thin syrup thus obtained is then filtered and concentration is completed in the second pan.

Steam-heated Pans.—The steam-heated pan evaporator is similar in principle to the sorghum pan and is a long, shallow, open, wooden box, lined with copper or tin, in which the juice is boiled by a closed steam coil, usually of copper. The coil extends the full length of the evaporator and is removable.

The coil is covered with juice to a depth not to exceed 1 in. above the coil. The method of operation is the same as for the sorghum pan, but there is less danger of scorching, and the rate of concentration can be more accurately controlled than in the sorghum pan.

Steam-jacketed Kettles.—Steam-jacketed jelly kettles can be used for the preparation of syrups, but because the boiling process is necessarily prolonged, the product is apt to be of dark color and scorched in flavor.

Kettles Heated by Coils.—Tomato purée kettles of glass-lined steel or wooden tanks fitted with copper flash coils are also used for the concentration of syrups but are open to the same objection noted above for steam-jacketed kettles.

Concentration by Solar Heat.—Wet clothes dry rapidly when hung on a line in the open air on sunshiny days and drying is hastened if the day is windy.

These principles have been taken advantage of in a process for concentrating sugary liquids. The liquid is placed in a pan or tank; cheesecloth is dipped in the juice and hung above the tank to dry. In drying, water is removed by solar evaporation and a concentrated solution remains on the cloth. The cloth is wrung out, dipped in the juice, and dried repeatedly until the liquid in the reservoir has attained the desired concentration.

This method is particularly adaptable to small-scale operations, yielding a syrup of brown or dark-amber color and pleasing flavor, but to the writer's knowledge has never been used upon a large commercial scale.

Spray Process.—Milk is concentrated to a powder by forcing it in the form of a fine spray into a large chamber through which a current of heated air passes. The same principle and apparatus have been applied successfully to the concentration of some fruit juices to a powder.

In one form of spray-drying apparatus the liquid is sprayed into a large chamber into a current of heated air and the resulting powder is recovered in air-settling chambers or bag filters beyond the drying chamber.

In another machine the drying chamber consists of an inverted cone surmounted by a large cylinder, all of sheet metal, into which air heated by steam coils is forced tangentially by a powerful fan. The air is thus given a whirlwind motion within the chamber. The liquid is sprayed

from a nozzle into the center of the "whirlwind," the droplets travel outward from the center toward the walls by centrifugal force and as they travel meet air of increasing temperature and decreasing humidity. When they reach the walls, they have dried to a powder and settle into the conical bottom of the chamber as a fine dust.

The spray process can be used for drying some fruit juices, although it is usually necessary to mix with the juice milk, milk sugar, cane sugar, or dextrose to prevent formation of a syrup after drying. In experiments made with grape juice with a milk-drying machine, it was found that, although the juice was dehydrated successfully, it melted at the temperatures used in drying (130 to 240°F.), because of the large proportion of fructose in the juice. On cooling, the product became solid and glass-like in appearance but was very hygroscopic and became a syrup after a few hours' exposure to air.

Lemon juice and orange juice have been dried successfully by the Merrill-Soule Company, after the addition of refined corn sugar, dextrose.

Concentration by Freezing.—It has long been a common practice in the making of maple syrup to permit the sap to freeze. Ice separates in practically pure form, leaving a sap concentrated in proportion to the amount of ice that has formed. This principle has formed the basis of several methods of concentrating fruit juices and other solutions.

Gore Process.—In a process described and tested upon a commercial scale by Gore, the juice is placed in a freezing room or in ordinary ice cans surrounded by cold brine and is frozen to a mushy mixture of ice crystals and dilute syrup or is frozen to a solid cake. It is then broken up by an ice crusher and is placed in the basket of a sugar centrifuge operated at moderate speed. The basket is a perforated cylinder attached to a vertical shaft and is surrounded by a heavy metal wall. The whirling of the centrifugal forces the syrup through the openings in the basket, and the ice remains in the basket, where it may be washed free of syrup by a fine spray of water while the centrifuge is still in motion. The syrup collects in the chamber surrounding the basket and flows from the centrifugal by a suitably arranged outlet pipe.

The syrup is dilute and must be frozen and centrifuged at least once again to obtain a syrup of 50° Balling. The second freezing is carried out at a lower temperature than the first, because concentration lowers the freezing point. The writer has obtained satisfactory results by conducting the first freezing at 10 to 15°F. and subsequent freezings (usually three) at 0 to 5°F. A syrup of 54° Balling was obtained. This must be held in cold storage or pasteurized to prevent spoiling.

Juice concentrated by freezing possesses a richer fresh fruit flavor than that concentrated by any other known process, because the flavor and aroma of the fresh juice are not evaporated.

The method at one time was used commercially in the Hawaiian Islands at Pearl Harbor for the concentration of pineapple juice.

Energy Requirement.—The latent heat of freezing of water is 80 cal. and of evaporation 537 cal., nearly seven times as much energy being required to evaporate as to freeze a unit quantity of water. Therefore, theoretically at least, it should be more economical to concentrate a fruit juice by freezing than by the direct application of heat. In practice, however, the freezing process has proved more costly, because of its less direct use of energy which involves development of mechanical energy, sometimes from burning fuel, and conversion of the mechanical energy to heat energy, with loss of energy in both operations; and because of the large amount of handling necessary in repeatedly freezing and centrifugalizing the juice and syrup.

Monti Process.—In the Monti process the syrup and ice crystals are separated by draining, and a centrifuge is not employed. This process is in commercial use in Italy.

CONCENTRATION IN VACUO

Boiling in the open usually results in caramelization of the sugars of the liquid undergoing concentration and in excessive loss of flavor by evaporation and decomposition through heat. If the atmospheric pressure is to a large degree removed by placing the liquid under a vacuum, the boiling point of the liquid is reduced, and much of the harmful effect of high boiling temperatures is avoided.

Relation of Boiling Point to Vacuum in Inches of Mercury.—Barometric pressure is usually expressed in inches of mercury. Vacuum degree is usually expressed in a similar manner, although reduced pressure (or "vacuum") is also often expressed in inches of mercury pressure or millimeters of mercury pressure. Thus, 2 in. pressure is approximately equal to 28 in. vacuum. A perfect vacuum at sea level would be 0 in. positive pressure, or approximately 29.9 in. vacuum.

At atmospheric pressure at sea level water boils at approximately 212°F., and in a perfect vacuum the boiling point is below the freezing point of water (32°F.); in fact, ice can be made by placing water under a very high vacuum.

At 29 in. vacuum, water boils at a temperature below 100°F., a temperature which results in no caramelization of fruit sugars and in very little injury to color and flavor. Table 45 gives the relation between vacuum and the boiling point of water. Owing to the presence of dissolved solids, syrups boil *in vacuo* at temperatures somewhat above those given for water.

General Description of Vacuum Pans.—A commercial vacuum concentrating apparatus is commonly known as a vacuum pan.

Boiling Chamber.—The primary part of a vacuum pan is a vessel in which the liquid is heated. This is usually cylindrical, fitted at the bottom with a steam jacket, and contains large steam coils or a tubular calandria to heat the liquid. A large outlet at the top connects to a vapor condenser and a vacuum pump (see Fig. 57).

The pan is often constructed of copper but may be made of glass-lined steel or of aluminum stainless steel or other material resistant to the action of juices.

Walls.—The walls must be heavy in order not to collapse when a vacuum is applied. The bottom must be particularly heavy because

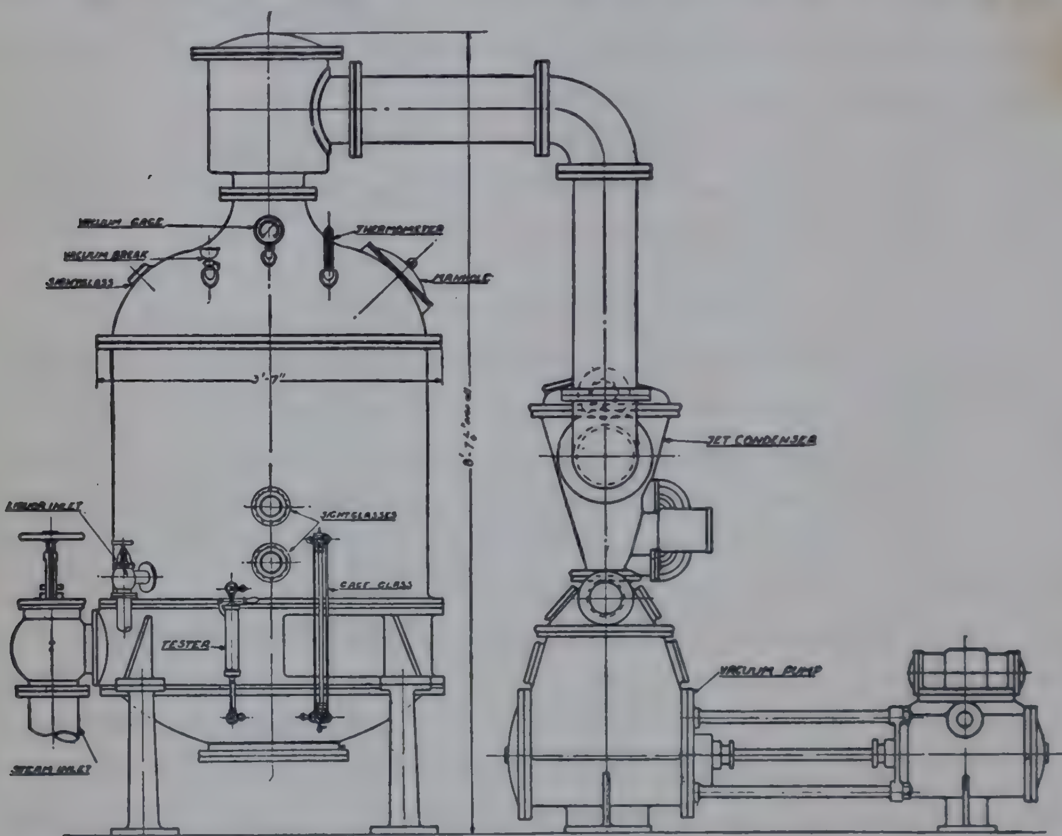

FIG. 57.—Sketch of vacuum pan with jet condenser and wet vacuum pump. (*Courtesy The Oscar Krenz Co.*)

the steam pressure in the jacket and the vacuum in the pan operate in the same direction. Thus a steam pressure of 50 lb. per square inch and a vacuum of 29 in. would be equivalent to about 65 lb. total strain per square inch.

Traps and Valves.—The pan should be surmounted by an entrainment trap or dome to check the carrying over of liquid as a froth or spray. Sight glasses, inlet valves for fresh liquid, outlet valves for concentrated liquid, and a suitable device for the removing and testing of samples during the boiling process are usually provided.

Calandria.—The most common heating device used in vacuum pans is the calandria. This consists of a large number of vertical steam-jacketed metal tubes resting near the bottom of the pan. The tubes are

open at both ends and are joined by heavy metal plates, forming a honeycomb structure. The liquid fills the tubes and the space beneath the calandria and is heated by contact with the tubes.

For the concentration of delicately flavored fruit juices, high-pressure steam should not be used as a source of heat because of the danger of local overheating. The circulation of water at 110 to 150° or steam at less than atmospheric pressure in the coils, jacket, or calandria is less liable to cause injury. This plan has been followed in several commercial plants with marked success.

Vacuum Pumps.—Several methods of producing a vacuum, *i.e.*, removing air and noncondensable vapors, are in commercial use.

Wet Vacuum Pump.—A very common form of pump is the "wet" vacuum pump, which is usually a cylinder and piston pump of large diameter which pumps, not only the noncondensable gases and air, but also the condensed water vapor and the water from the jet condenser used in condensing the water vapor from the pan. Figure 57 will make clearer the general design of such a vacuum pan and pump. The wet vacuum pump rarely gives in commercial practice a vacuum in excess of 26 in. mercury, which is not sufficient for the satisfactory concentration of fruit syrups.

Dry Vacuum Pump.—By means of a dry vacuum pump and a surface or barometric condenser it is possible to maintain under commercial operation a vacuum of 28 in. or more.

The dry vacuum pump is usually a rotary high-speed pump, the working parts of which turn in heavy mineral oil and which is similar to the small vacuum pumps in use in most analytical laboratories.

A condenser is interposed between the vacuum pump and vacuum pan in such manner that the pump cares only for air and other noncondensable gases which enter the pan through leaks or in solution in the fresh liquid.

Figure 58 illustrates one method of using a dry vacuum pump.

Jet Pumps.—The water-jet vacuum pump is familiar to all students of analytical chemistry. This pump, in a much enlarged form, is employed in some commercial installations. Water flowing rapidly past an opening entrains air and other gases from the pan and produces a vacuum, which varies with the water pressure, temperature, and volume of water used. It is not so satisfactory as the dry vacuum pump or the steam-jet pump.

A steam jet using steam under high pressure (100 lb. per square inch or more) is employed in a recently developed vacuum pump, which operates on the principle of the steam injector used to inject water into boilers, produces a high vacuum, and is apparently satisfactory in commercial operation.

Jet Condenser.—A jet condenser consists of a chamber with baffle plates into which is forced a stream or spray of cold water, which comes

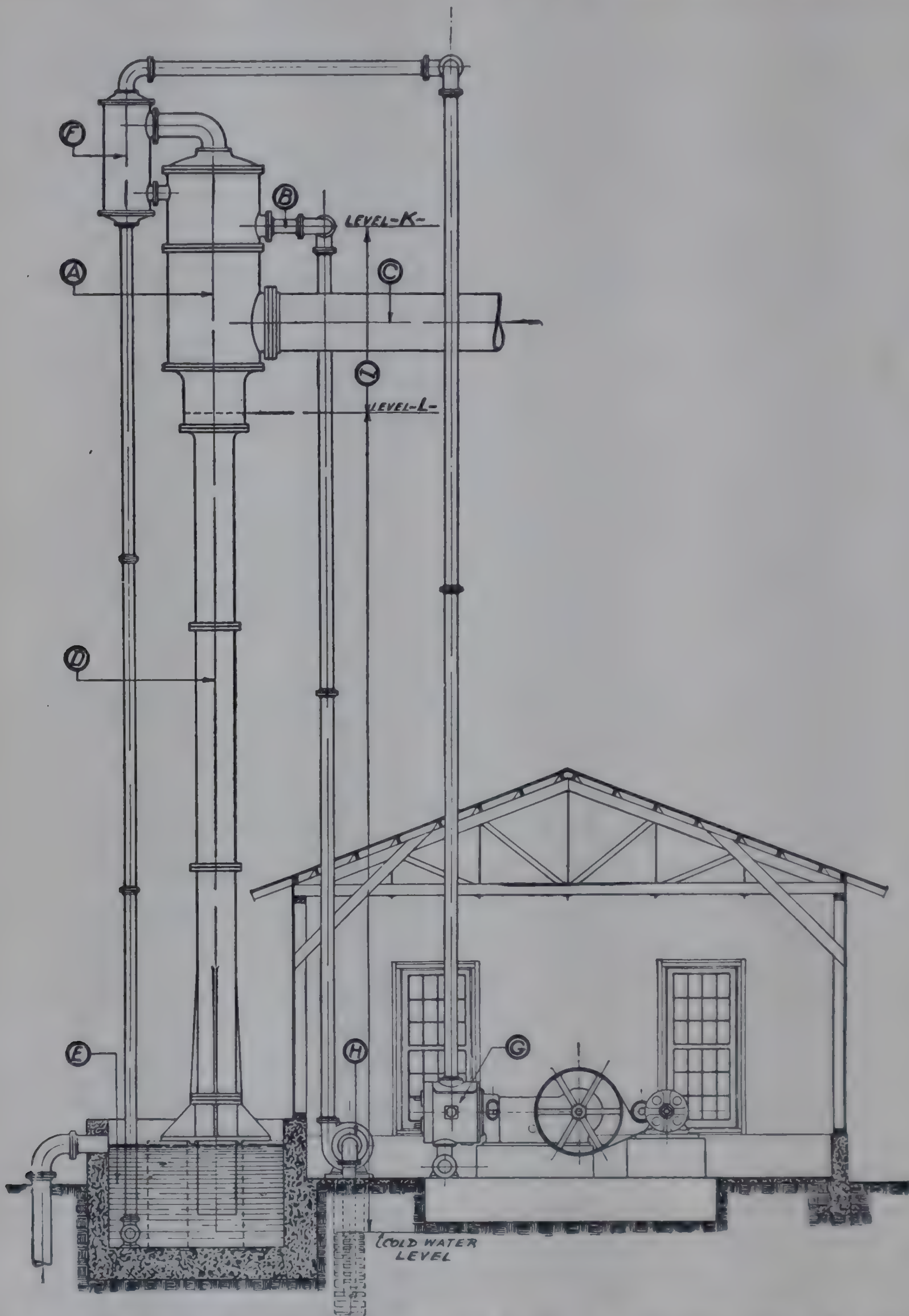

FIG. 58.—Sketch of dry vacuum pump installation. *A*, condenser head; *B*, inlet for condenser water; *C*, vapor inlet; *D*, barometric column; *E*, hot well; *F*, water separator; *G*, dry vacuum pump; *H*, water recirculating pump; *I*, working head of pump *H*; *K*, level of water injector; *L*, level of barometric column. (*After E. E. Horstmann, Fulton Iron Works.*)

in direct contact with and condenses the vapors from the vacuum pan. This method is efficient and economical in its use of water. The water

used in the condenser and also the condensed vapors are removed by a wet vacuum pump or by means of a barometric system (see Figs. 57 and 58).

Surface Condenser.—The surface condenser consists of a water-cooled coil or series of hollow plates or pipes into which the vapors pass and are condensed by contact with the water-cooled walls of the condenser in much the same manner as vapors are condensed in a laboratory-size glass condenser of Liebig's pattern.

Barometric Leg.—The condenser may be attached to a "barometric leg" and "hot well," *i.e.*, a vertical pipe at least 31 ft. high which dips beneath the surface of a tank or reservoir fitted with an overflow pipe (see Fig. 58). Water rises in the pipe in proportion to the vacuum applied to the system and flows from the hot well as rapidly as it collects in the barometric leg or standpipe. The condenser is usually of the water-jet type but, if desired, may be a surface-cooled condenser. Such a condenser with pipe is known as a barometric condenser because it is in contact with the atmosphere. The barometric column of water aids in maintaining the vacuum. The barometric standpipe or leg must be high enough to prevent flow of water from it to the vacuum pan.

Relation of Temperature of Condenser Water to Vacuum.—The lower the temperature of the condenser water the higher the vacuum it is possible to maintain in a given vacuum-concentrating system. Thus with condenser water at 32°F. it is possible to maintain a vacuum of 29.82 in., provided, of course, a suitable vacuum pump is used. If the temperature of the condenser water is 90°F., it is possible to maintain a vacuum of only 28.58 in. of mercury, referred to atmospheric pressure of 30 in. of mercury.

Table 45 gives the relation between the temperature of condenser water and the maximum vacuum. These figures also represent the relation between the boiling point of water and vacuum in inches of mercury.

Water Required for Condensing.—The amount of water required for condensing a pound of steam varies greatly with the temperature of the condenser water and the vacuum degree maintained in the system. At 29 in. vacuum, and condenser water at 50°F., 90 parts of cooling water are required to condense 1 part by weight of water vapor. Less water is required at lower vacuums.

Considerably less condensing water is required for a vacuum-concentrating system using a dry vacuum pump than for one using a wet vacuum pump. This is true because when the dry vacuum pump is used the difference in temperatures of the condenser water and the vapors evolved in the pan can be less. In the use of the wet pump there must be a considerable difference in temperature between the condensate and

the vapors from the pan in order that the desired vacuum may be maintained. The spent water from the condenser may be cooled by passage through a cooling tower and may then be used again. Such cooling is standard commercial practice.

Heat Requirements.—It is a popular misconception that a great deal less heat is required to evaporate water under a vacuum than at atmospheric pressure, but the heat required in either case is that required

TABLE 45.—RELATION BETWEEN TEMPERATURE AND PRESSURE OF SATURATED STEAM

(*After E. E. Horstmann, "Steam Condensing Plants"*)

Temperature, degrees F. of condenser water	Pressure, pounds absolute	Vacuum in inches of mercury
32	0.0886	29.82
35	0.0999	29.80
40	0.1217	29.75
45	0.1475	29.70
50	0.1780	29.64
55	0.2140	29.56
60	0.2562	29.48
65	0.3054	29.38
70	0.3626	29.26
75	0.4288	29.13
80	0.5050	28.97
85	0.5940	28.79
90	0.6960	28.58
95	0.8130	28.35
100	0.9460	28.07
105	1.0980	27.75
110	1.2710	27.41
115	1.4670	27.01
120	1.6890	26.56
125	1.9380	26.04

NOTE.—The above vacuums are referred to a barometer of 30 in.

to heat the liquid to the boiling point, plus the latent heat of vaporization of water. The latter quantity is several times greater than the former and is practically the same whether evaporation occurs at atmospheric pressure or *in vacuo*. Therefore, the principal saving in heat in evaporating *in vacuo* is in that used to heat the liquid to the boiling point. Thus if the boiling point is 212°F. at atmospheric pressure and 105°F. *in vacuo* and the initial temperature of the liquid is 60°F., the liquid must be raised 152°F. if boiled in the open and only 45°F. if boiled *in vacuo*. The saving in this case would be 107°F.; or in the evaporation of 1 lb.

of water, 107 B.t.u.; or in the evaporation of 1 gram of water, about 59 cal.

A British thermal unit is the amount of heat required to raise 1 lb. avoirdupois of water 1°F. A small calorie (1 cal.) is the amount of heat required to raise 1 cubic centimeter (1 gram) of water 1°C.; a large calorie (1 Cal.) is the heat necessary to raise 1 liter of water 1°C. One B.t.u. equals 0.252 Cal. (252 cal.).

The latent heat of vaporization of water at atmospheric pressure at 212°F. is 970.4 B.t.u. and at 105°F. is 1032.9 B.t.u. The following table shows the relation between the latent heat of vaporization (B.t.u.'s

TABLE 46.—RELATION BETWEEN TEMPERATURE OF VAPORIZATION, LATENT HEAT OF VAPORIZATION OF WATER, AND BOILING POINT

(*After The Lillie Evaporator Co. Tables*, 1918)

Temperature F.	Vacuum inches mercury	Latent heat, in B.t.u.
32	29.8191	1,073.40
40	29.7516	1,068.90
50	29.6365	1,063.30
55	29.5631	1,060.50
60	29.4770	1,057.80
65	29.3760	1,055.00
70	29.2590	1,052.20
75	29.1250	1,049.40
80	28.9680	1,046.80
85	28.7880	1,044.00
90	28.5800	1,041.20
95	28.3410	1,038.40
100	28.0700	1,035.60
105	27.7590	1,032.90
110	27.4040	1,030.10
115	27.0050	1,027.30
120	26.5530	1,024.40
125	26.0400	1,021.60
130	25.4800	1,018.81
135	24.8300	1,015.90
140	24.1100	1,013.10
150	22.4200	1,007.40
160	20.3200	1,001.60
170	17.7700	995.80
180	14.6700	989.90
190	10.9300	983.90
200	6.4700	977.90
210	1.1600	971.60
212	0.0000	970.40

necessary to change 1 lb. of water into steam) and the temperature and vacuum at which vaporization takes place.

Multiple-effect Vacuum System.—In sugar factories the sugary liquids are concentrated in multiple-effect vacuum pans, *i.e.*, several pans, usually four or five, which are connected in series in such a manner that the vapors from the first pan pass through the heating system of the second and the vapors from the second pass through the heating system of the third, and similarly for the remaining members of the system.

The boiling point of the liquid in pan 1 is usually above 212°F., in 2 slightly less than 212°F., and the temperature in each succeeding pan is sufficiently less than in the preceding pan so that the vapor from the latter will cause boiling to take place. By this method the heat applied to vaporize the liquid in pan 1 is used repeatedly in succeeding pans, by the simple device of maintaining different degrees of vacuum in the different pans. This system has been used in the concentration of sorghum syrup on a large scale and in sugar factories. Because of the high temperature necessary in the first pan, the writer doubts the applicability of this system to the evaporation of fruit juices.

FRUIT SYRUPS

The manufacture of syrups affords a means of utilizing a considerable portion of cull and second-grade fruit of sound condition.

Grape Syrup.—Grape syrup may be prepared from any variety or color of grape, but the process of manufacture will vary with the character of the finished product and the proposed utilization. The grapes should be fully mature in order to be of maximum sugar content and optimum flavor.

Preparation of the Juice.—White grapes are crushed but are not heated before pressing. Red grapes are crushed, stemmed, and heated to 120 to 160°F. to extract the color from the skins. The grapes are then pressed as described for the preparation of grape juice for bottling. The juice should be clarified by filtration after heating to 160°F. to coagulate proteins.

Grape Syrup for Beverage Purposes.—Grape syrup to be used in beverages must possess a marked fresh grape juice flavor and deep red color. Any of the Labrusca or Scuppernong varieties used for red grape juice, or a blend of equal parts of red Vinifera juice, such as Zinfandel, Petite Sirah, etc., with Muscat or other highly flavored white Vinifera juice can be used.

The most common method of concentration is in a vacuum pan under a high vacuum (at least 28 in. mercury). The pan must be constructed of material which will not injure the color or flavor of the juice. Direct contact with copper, tin, iron, or zinc causes the red grape

color to turn brown or to precipitate and, if the action is prolonged, will impart a metallic taste. A glass-lined pan with steam jacket and flash coil of aluminum or other metal insoluble in the juice is satisfactory for the purpose. Copper is less objectionable than tin. Stainless steel is best for vacuum pans or coils.

Concentration by boiling *in vacuo* results in loss of considerable of the grape aroma, but it is possible to collect the distillate and by fractional distillation *in vacuo* to concentrate it to a small volume and return it to the syrup. The Seralian process depends on this principle.

It is also feasible to concentrate part of the juice by the freezing method described earlier in this chapter and to obtain thereby a highly flavored syrup, which can be blended with syrup concentrated by the usual vacuum pan method. Muscat syrup produced by the freezing method is particularly rich in flavor and desirable for blending purposes.

Grape Syrup for Table Use.—Excellent table syrup can be prepared from clear grape juice by concentrating the juice in a vacuum under 28 to 29 in. vacuum. If made from red grapes, it will be of deep purplish-red color and of a rich, berry-like flavor, which is very desirable for table use.

It is possible to neutralize all or most of the acid of grape juice by the addition of calcium carbonate or calcium hydroxide. Insoluble calcium tartrate is formed and can be separated from the juice by settling, racking, and filtering. The calcium tartrate forms most readily at or near the boiling temperature and is most insoluble at low temperatures. Therefore, the juice should be heated to facilitate the reaction and should be allowed to cool before filtration. Not all of the acid should be neutralized. The juice should retain about 0.1 per cent acidity (as tartaric) after neutralization. Complete neutralization results in darkening of the syrup and renders it more liable to injury in flavor during concentration.

The partially neutralized juice can be decolorized by the use of vegetable decolorizing carbon. A light-colored syrup of neutral flavor can then be produced by vacuum-pan concentration.

Grape and other fruit syrups in which part of the acid has been neutralized or from which both acid and color have been removed must compete with cheap table syrups and, therefore, usually do not afford a profitable means of utilizing grapes or other fruits.

Preservation of Grape Syrup.—Grape syrup is best preserved by pasteurization in bottles or enamel-lined cans, accomplished by heating the syrup to 165°F. in sealed containers for 20 min.

The pasteurized syrup should be cooled to room temperature as rapidly as possible to prevent loss of flavor and color by prolonged heating, since grape syrup rapidly darkens at temperatures above 130°F.

If the concentration of the syrup exceeds 68° Balling, it may usually be stored for several months without danger of fermentation; but crystallization of the dextrose sugar is apt to occur in such highly concentrated syrup.

The syrup may also be satisfactorily stored at 26°F. or lower temperatures. At 32°F. molding often occurs.

The use of sodium benzoate as a preservative for fruit syrups should be avoided.

Crystallization of Sugar in Grape Syrup.—White grape syrup will usually become a semisolid mass of dextrose crystals at concentrations above 65° Balling. Syrup from red grapes heated before pressing does not exhibit this tendency so frequently as the white syrup, because of the inhibiting effect of gums and pectins extracted by the heating of the crushed grapes. The addition of dextrin or of cane sugar to the syrup retards or, if used in high enough concentration, prevents the crystallization of dextrose in white syrup.

Separation of Cream of Tartar.—Grape juice is a saturated solution of cream of tartar—acid potassium tartrate, $KH(C_4H_4O_6)$—and concentration of the juice to a syrup causes the excess cream of tartar to crystallize. Much of the cream of tartar separates as a fine-grained "sand" during concentration, but a considerable proportion crystallizes only very slowly after concentration. In using the syrup for some purposes the presence of the cream of tartar is not objectionable, but generally the syrup should be as nearly free from the crystals as possible. If the syrup is stored for several weeks, the excess cream of tartar separates almost completely.

Yield of Syrup.—Grapes if thoroughly crushed and pressed yield from 160 to 185 gal. of juice per ton. The pomace can be treated with hot water and pressed to recover most of the residual juice, amounting to 15 to 30 gal. per ton of grapes.

The yield of syrup from a given volume of juice varies with the per cent of total dissolved solids (Balling degree) of the juice in accordance with the following formula

$$G = \frac{b \times s}{B \times S} \times g$$

Where G = gallons of syrup; g = gallons of juice; b = Balling degree of juice; s = specific gravity of juice; B = Balling degree of syrup; S = specific gravity of syrup. By application of this formula it will be found that 100 gal. lots of juices of 18, 19, 20, 21, 22, 23, 24, and 25° Balling will yield 22.5, 23.9, 25.2, 26.6, 28, 29.4, 30.8, and 32.1 gal., respectively, of syrup of 65° Balling.

Apple Syrup.—In the past, apple syrup has been used almost exclusively for culinary purposes. If properly prepared, however, it is suitable for soda-fountain use and the preparation of bottled beverages.

Preparing the Juice.—If the syrup is to be used for beverage purposes, the apples should be of suitable quality for making sweet cider. For preparing boiled cider for culinary purposes, peels, cores, and apples of all varieties may be used.

The raw material must be sound, carefully sorted, and washed. It must be free of poisonous-spray residues such as arsenic, lead, and fluosilicates. Crushing and pressing are conducted as in preparing juice for bottling.

The juice should be made as clear as possible before concentration. This should be done by the enzyme method mentioned on page 301.

Concentration.—Gore has demonstrated that an excellent concentrated cider suitable for beverage purposes can be prepared by the freezing method described earlier in this chapter.

Concentration *in vacuo* at 28 to 29 in. vacuum in a stainless-steel pan heated with water at 120 to 150°F. also yields an excellent product. If concentration is carried beyond 60° Balling, jelling is apt to take place because of the pectin present in the juice. However, if the juice is previously treated with a pectic enzyme jelling will not occur.

The usual method of concentration is by boiling in a shallow, open wooden box fitted with a copper steam coil, the operation of which is similar to that of a sorghum pan. A direct-fired sorghum pan can also be used. In either case the syrup produced is only suitable for table use or culinary purposes.

Preservation.—Boiled cider usually keeps without sterilizing. Vacuum-concentrated syrup or that made by the freezing process and of 50 to 60° Balling should be pasteurized at 165°F. in order to prevent fermentation or molding.

Pear Syrup.—Pear syrups similar in composition to concentrated apple juice can be prepared. These possess a rich, baked-pear flavor and are suitable for table or culinary use.

Orange Syrup.—Orange syrup is in great demand for the preparation of carbonated beverages.

In some cases the juice is extracted by crushing and pressing the entire fruit. The juice should be "flash pasteurized," *i.e.*, heated to 180 to 185°F. for a few seconds before conversion into syrup in order to destroy the oxidase responsible for changes in flavor during storage of the syrup. The usual method of preparing the syrup is by adding 12 lb. of sugar per gallon. The syrup should be placed under 28 to 29 in. vacuum at room temperature for 25 to 30 min. to remove dissolved air and should then be sealed airtight in completely filled bottles, lacquered

cans, or jugs. The presence of air in syrup or container causes the oil to oxidize and become "terpeney" in flavor.

Syrup is also prepared commercially by extracting the juice and yellow pulp on revolving aluminum, bronze, or porcelain cones, and oil from the skins is excluded. The juice is strained through a coarse screen, and sugar to increase the Balling to 65 to 70° is added, together with benzoate of soda, $\frac{1}{10}$ per cent. Lemon juice or citric acid may also be added.

Another popular product is prepared by partially concentrating the juice *in vacuo* and adding cane sugar. The syrup is pasteurized in cans or bottles and used in preparing 5-cent drinks by diluting with water. These drinks are sold widely through dairy products distributors. The syrups usually contain added citric acid. Artificial color is usually omitted, although a small amount of oil may be added for flavor.

All orange syrups tend to deteriorate in flavor during storage.

If the product is pasteurized at 165°F., sodium benzoate can be omitted from orange syrup.

C. P. Wilson, when chemist for the Exchange Orange Products Company, of California, found that orange juice can be concentrated to a heavy syrup in a stainless-steel or a glass-lined vacuum pan successfully, provided a high vacuum (at least 28 in.) is maintained. This syrup is now in commercial use by soda-water bottlers and fountains. The vacuum-concentrated syrup requires the addition of no sugar and, therefore, uses much more fruit per gallon of syrup than the syrup prepared from juice and cane sugar. In practice, however, a small amount of sugar is usually added before concentration.

Other Citrus Fruit Syrups.—The principles and methods discussed above in connection with orange syrup also apply to the preparation of syrups from other citrus fruits. Lemon syrup tends to deteriorate more rapidly in flavor than orange syrup, but grapefruit syrup retains its flavor very satisfactorily.

Berry Syrups.—Berry syrups are used extensively in soda fountains for carbonated drinks and for dressings for ice creams. They should find wider use than is the case at present, for production of carbonated bottled drinks and in the household in the preparation of fruit punch, gelatin desserts, cake fillings, etc.

The berries should be thoroughly ripe, free from mold or fermentation and should be carefully sorted and washed. Strawberries need not be hulled.

The berries are crushed, heated to about 160°F., pressed, and the juice filtered. Sugar can then be added to increase the Balling degree to about 60 to 65° for strawberry and raspberry juices. Loganberry, currant, and sour blackberry syrup will often jelly if the sugar concentration exceeds 50° Balling. Pulpy berry syrups are also made.

If the syrup is to be stored at room temperature, it should be pasteurized in bottles or enamel-lined cans (see Chap. XV).

Excellent syrups, more concentrated in flavor and color than those described above, can be made by the freezing process. The Balling degree of the juice should be increased to about 20 to 25 per cent by addition of sugar before freezing, or sugar should be added after the second freezing and centrifuging of unsweetened juice to increase the concentration to about 50° Balling. The added sugar reduces the tendency of the juices to oxidize and change in flavor.

FIG. 59.—Vacuum-pan assembly for concentrating fruit juices. (*Courtesy Pfaudler Co.*)

Strawberry syrup is usually deficient in color, but the addition of a small proportion (10 to 20 per cent) of blackberry syrup produces a blend of rich strawberry flavor and of bright-red color.

Berries do not yield palatable syrups without the addition of sugar although they have been concentrated by freezing and *in vacuo* successfully by the Seralian process, in which the volatile flavoring compounds are recovered and returned to the concentrated juice.

Pomegranate Syrup.—Pomegranate juice prepared as described in Chap. XV yields a syrup suitable for soda-fountain and bottling use when sugar is added to increase the Balling degree to about 40°. This syrup blends well for beverage purposes with citrus juices. True

grenadine syrup should be made from pomegranate juice, but most so-called "grenadine" syrup is a purely synthetic preparation.

Syrups from Dried Fruits.—Low-priced dried fruits of sound quality are sometimes used for the preparation of syrups for use in medicines or for table syrup. The fruit can be extracted with water in any one of several ways.

It can be soaked in water until plump (24 hr.) and then crushed and pressed in the usual manner. The press cake should be soaked and pressed a second time.

The fruit may be heated in several changes of water, and the dilute extract so obtained can be used to extract succeeding lots of fruit until an extract is obtained rich in sugar and requiring very little concentration by boiling. This procedure is very successful with dry prunes.

The dry fruit may be crushed or shredded and extracted by percolation with hot water or by diffusion in a series of tanks arranged as in a sugar beet diffusion battery.

The sugary extracts prepared in any of the above ways must be further concentrated by boiling in the open or *in vacuo* or concentrated by some other suitable method. Because of their mild laxative action, syrups from dried prunes or figs are in use in certain pharmaceutical preparations. Incidentally, syrups made from California prunes are much more laxative than fig syrup.

Raisin syrup and syrup from other dried fruits are suitable for table and culinary purposes. The sugary extract from raisins can be neutralized with calcium carbonate, decolorized with vegetable carbon, and concentrated *in vacuo* to give a water-white syrup. However, this syrup darkens during subsequent storage.

Carefully dehydrated berries can be used for the preparation of syrups for soda fountain use and for bottling purposes.

SORGHUM SYRUP

Sorghum syrup is produced extensively throughout the Southwest and Middle Western states. The process of manufacture is simple and does not require expensive equipment. For this reason the syrup is more frequently produced on a small scale on individual farms than in large centrally located factories.

Wright gives the approximate annual production of the more important table syrups in the United States as follows:

	Gallons per Year
Sugar cane syrup	35–40,000,000
Corn syrup	30–35,000,000
Sorghum syrup	25–30,000,000
Molasses	25–30,000,000
Maple syrup	3– 5,000,000

Sorghum syrup is usually of heavy consistency varying from 70 to 80° Balling, the color is light brown to amber, and the syrup possesses a pleasing flavor characteristic of the sorghum cane. Its principal use is as a table syrup, but it is also often used in cooking as a substitute for "New Orleans molasses" or sugar.

Harvesting.—Sweet sorghum cane contains the maximum of recoverable sugar when the grain has reached the hard dough stage. The effect of maturity is shown by the results of analyses of 2,740 samples of sorghum by Collier and reported by Bryan.

If cut too green, the sap will be low in sugar, and the syrup will be of poor flavor. If cut too ripe, the cane will be dry, and the yield of sap low.

The leaves, sucker, seed heads, and seed stems injure the flavor of the sap and are removed before the canes are crushed. In many cases this is done by hand in the field. A piece of wood sharpened on one edge is used to cut the leaves from the canes, the operation being known as "stripping." The heads and 6 to 12 in. of the seed stem are cut from the standing canes with a corn knife, although in some cases the stripped cane is cut with a binder and the heads are cut from the canes in the bundle. The seed heads can be collected in piles and hauled to a drying yard or shed. The leaves are more difficult to recover, although if the cane is cut promptly after stripping it is possible to rake the leaves and utilize them for silage or for feeding in the fresh state to stock.

TABLE 47.—SUGAR CONTENT OF SORGHUM CANE AT VARIOUS STAGES OF GROWTH
(*After Bryan*)

Stage of cutting	Total sugar, per cent	Sucrose, per cent	Invert sugar, per cent
Panicles just appearing	6.05	1.76	4.29
Panicles entirely out	8.01	3.51	4.50
Flowers all out	9.28	5.13	4.15
Seed in milk stage	11.24	7.38	3.86
Seed in dough stage	12.14	8.95	3.19
Seed dry, easily split	13.01	10.66	2.35
Seed hard dry	13.50	11.69	1.81

Machinery is available for removing the leaves and seed heads from sorghum cane which has been harvested without previous stripping of leaves and harvesting of seed heads in the field. Where such equipment is used the harvesting can be done by machinery.

It is usually desirable to crush the cane as soon as possible after harvesting in order to avoid deterioration through "heating" and fermentation. Frozen cane quickly develops fermentation on thawing.

Extraction of Juice.—Sorghum cane contains 70 to 80 per cent of water. It is possible to obtain, with thorough pressing, a yield of juice equal to from 50 to 60 per cent of the weight of the cane.

The juice is extracted by passing the cane between the iron rolls of a cane mill. The simplest mill consists of two vertical rolls operated by a sweep and horsepower, the distance between the rolls being adjusted to suit the size of cane and the rate of feeding. The three-roll mill is more powerful than the two-roll mill and gives a higher yield of juice. The cane first passes between two of the rolls set at a medium distance

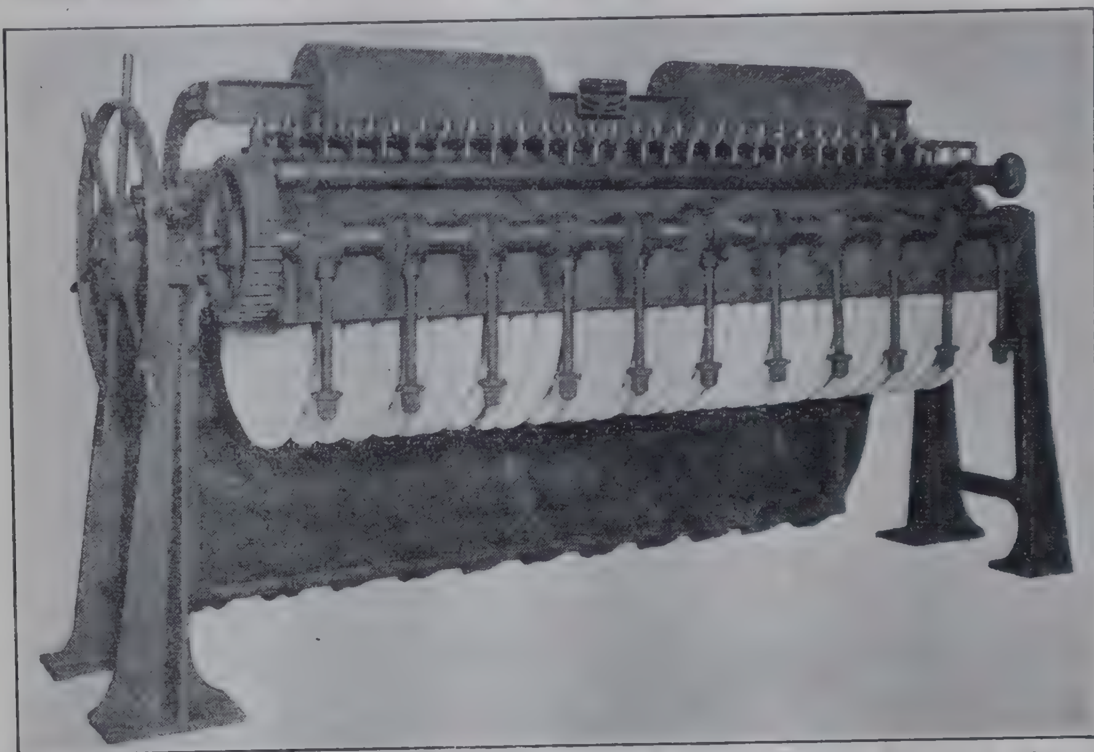

FIG. 60.—Large sweetland "clam shell" filter press suitable for the filtration of sorghum, cane and other juices or syrups. (*Courtesy United Filters Corporation.*)

apart and then between the second and third rolls, which are set very closely together and exert a very heavy pressure.

Clearing the Juice.—The undissolved impurities may be removed to a large extent by settling of the freshly pressed sap in tanks or barrels of suitable size. Long shallow tanks with baffles to retain sediment or floating materials are sometimes used for the continuous settling of the sap.

The juice is rich in heat-coagulable compounds which aid in the clarification, when the fresh juice is heated. The normal procedure is to skim the juice and syrup by hand during the boiling process and thus remove both the coagulated proteins and sediment occluded by the coagulated material.

In large syrup establishments the sap may be heated to boiling after adding infusorial earth and then filtered through a filter press or pulp filter, a method which is less wasteful than the skimming method.

The sap may be clarified by boiling and settling with a suitable quality of clay in much the same manner as described in Chap. XV for the fining of fruit juices with Spanish clay or bentonite clay. Fire clay is not suitable.

Concentrating.—The usual equipment for concentrating sorghum sap to syrup is the sorghum pan and furnace described earlier in this chapter. The juice enters one end of the pan, follows a zigzag path through the pan, and emerges at the opposite end as syrup. During its passage it boils vigorously and is skimmed to remove coagulated material and floating particles of pulp.

In some large factories the sap is concentrated in vacuum pans which produce a syrup of lighter color and with less caramelized flavor than is obtained in the open pan.

The syrup must be concentrated to at least 70° Balling (or Brix) cold test in order to prevent spoilage by fermentation or molding, but when concentrated too far, crystallization of cane sugar (sucrose) will occur. Crystallization is more apt to occur in syrup made from juice neutralized with calcium carbonate or hydroxide than in syrup made from juice not deacidified, because considerable inversion of the sucrose to dextrose and levulose occurs in the boiling of acid juice. Invertase may be used to invert most of the cane sugar, and then crystallization does not occur, as demonstrated by specialists of the U. S. Department of Agriculture.

The end point can be determined by a Balling saccharometer—the necessary correction for temperature—by refractometer, or by observing the boiling point. A syrup of 70° Balling boils at about 13°F. above the boiling point of water.

Deacidification.—Occasionally, in order to modify the flavor and to clarify the sap, slaked lime is mixed with water and added to the sap, or powdered calcium carbonate is added direct. Neutralization is conducted at the boiling point and the end point is determined by the use of litmus paper. It is doubtful whether the addition of lime or calcium carbonate results in the precipitation of more organic matter than occurs with boiling without such addition.

Treatment of the Syrup.—The finished syrup should be promptly cooled to avoid darkening of the color by prolonged heating. This can be done by allowing the syrup to flow through a coil immersed in cold water or in fresh juice; if in the latter, the heat of the syrup is utilized in preheating the sap.

Settling of the syrup or filtration through felt, sand, or other permeable filter is desirable. Some manufacturers filter the partially concentrated juice and thus avoid the necessity of settling or filtering the finished syrup.

The clear syrup is marketed in barrels, kegs, or cans.

Yields.—Under California conditions the average yield of unstripped cane is about 14 tons per acre, equivalent to about 12 tons of stripped cane, or about 130 gal. of syrup, per acre. On unirrigated land the yield is less and on rich, well-watered soil more than this. In most districts 100 gal. of syrup per acre is considered a satisfactory yield.

MAPLE SYRUP

At one time maple syrup and sugar were staple food products and their manufacture a very important industry. They are now considered delicacies, and the amount of true maple syrup and sugar is relatively so small, compared to the imitation maple, that it has been stated that the amount of "maple" syrup on the market would not decrease appreciably if none of the maple sugar trees in America were used for syrup production. Nevertheless, the maple syrup industry is still an important one.

Districts.—New England, New York, Pennsylvania, the Ohio Valley, the Lake states, and adjacent parts of Canada are the principal regions in which the sugar maple (*Acer saccharum*) is found in abundance and are the principal maple syrup producing regions. In the Southern States the sugar maples occur but do not appear to produce a sap suitable for syrup making.

Tapping.—The opening and closing dates of the maple sap season vary considerably from year to year according to the opening of spring and according to the locality. It may start as early as the middle of February or as late as the middle of April in a given locality. "Sugar weather" is a term well known to the syrup manufacturers and may be described as weather in which the temperature during the day rises above 32°F. and drops below the freezing point at night. If the season starts with bright sunny days the flow of sap will be very rapid and the season short. High winds check the flow of sap and unusually warm weather or a heavy freeze often stops it.

Holes.—To obtain the sap one or more holes are bored in the tree, and buckets are attached to a spout inserted in the holes. It is considered that more than one hole per tree shortens its life, and except in very large trees, one hole will suffice. The hole should be located at a place where the bark and wood are healthy and vigorous in order to reduce liability of infection and decay. The hole is ordinarily located at a convenient height for the workman, usually about waist-high. The size of the hole should be such that it will heal over completely in one season, a hole 3/8 to 1/2 in. in diameter usually being considered best. A small hole may be reamed out to obtain a second flow of sap should weather conditions become favorable. The hole is bored with a slight upward slant to favor flow of sap from the hole and to reduce the tendency for the sap to ferment or sour. A sharp clean cutting bit should be used to avoid "feathering"

of the wood in the hole, with consequent souring of the sap in the roughened surface. The hole should pass through the sapwood only and should not penetrate the heartwood. Most trees will require a hole not more than 2 in. deep.

Spouts.—A spout or spile is inserted in the opening for collection of the sap. The best forms of spouts are perfectly cylindrical, smooth, and of even taper. This form may be easily inserted and removed without injury to the wood tissue. Spouts which are liable to split the bark or crush the sapwood should be avoided. The weight of the bucket should rest upon the bark and not upon the sapwood.

Buckets.—Metal buckets are to be preferred to wooden buckets for the collection of the sap, since they are lighter, more easily cleaned, and not so liable to become foul through fermentation and souring of the sap during warm weather. Heavily tinned buckets are more satisfactory than galvanized buckets because the zinc coating of the latter is fairly soluble in the sap. Buckets of slender rather than flaring design can be most conveniently hung to the trees.

Buckets should be covered in order to exclude rain, snow, insects, etc., and to reduce darkening of the sap by sunlight. Tapping buckets vary from 8 to 15 qt. in size.

The sap is gathered periodically in larger buckets and is poured into a hauling tank, usually mounted on a sled. Wooden tanks are more liable to become sour through fermentation of the sap in the wood pores than are metal tanks and if used should be painted on the inside. The sap is transported to the boiling house by means of the hauling tank.

Concentrating the Sap.—The sap contains from 1 to 5 per cent total dissolved solids, principally sucrose. During freezing weather the sap in the buckets will freeze at night and if not completely frozen the ice may be separated from the remaining sap and discarded; thus effecting a considerable concentration of the sap.

Concentrators.—At the boiling house the sap is concentrated as described elsewhere for sorghum sap, the sorghum pan being commonly used for this purpose. Iron kettles are frequently used by small producers and steam-heated pans by the larger factories. Wood is the usual fuel.

Iron kettles are objectionable principally because the sap is subjected to a prolonged period of boiling and becomes darkened or scorched in flavor. Boiling should be completed rapidly if a syrup of light color and good flavor is desired.

Skimming.—During boiling, proteins are coagulated and come to the surface and this coagulum is removed by skimming during the boiling operation. White of egg or other clarifying agents are sometimes added but are liable to alter the flavor of the finished product. The addition of

baking soda to cause the coagulated matter to rise to the surface is objectionable because it may so greatly reduce the acidity of the sap that the flavor is injured. pH control to near pH7 is desirable.

A separation of mineral salts, principally calcium malate, occurs during the boiling of the sap, and these are usually removed by settling of the syrup after boiling is completed.

Balling Degree.—Maple syrup is concentrated to about 65° Balling. If it is less than 65° Balling, it will ferment, and if above 70° Balling, it is very apt to crystallize, owing to the separation of sucrose. Syrup of 65° Balling weighs 11 lb. per gallon at 60°F. The sucrose may be inverted with commercial invertase, when crystallization is less apt to occur.

Canning.—Most maple syrup is sold in cans and bottles of quart, half gallon, or gallon size.

CANE SYRUP

Syrup is produced in the Southern States in commercial quantities from sugar cane by methods very similar to those discussed for sorghum syrup.

Culture.—A number of varieties of cane are used for the purpose but all of these belong to the species *Saccharum officinarum.* To be suited to profitable growth in the Southern States, the cane must be a quick-maturing variety, two of the best known varieties being the Louisiana Purple and the Louisiana Striped.

Harvesting.—Harvesting may begin in October, but more generally in November, and is accomplished by hand by much the same methods as used for sorghum cane. The leaves are first stripped from the cane and the cane is then cut by hand with a heavy knife.

Composition of Cane.—The composition of the cane varies with the season and other conditions, but normally 88 to 90 per cent of its weight is juice. By use of modern mills with 9 to 12 rollers it is possible to extract 80 to 85 per cent of the weight of the cane and with small mills less, even as low as 55 per cent.

The juice from cane produced in the Southern States contains about 11 to 14 per cent of sucrose, 1.5 to 2 per cent invert sugar, and about 1.3 to 2 per cent of solids other than sugar.

Yields and Costs.—Yoder estimates the cost of producing the first year's crop of cane at $54 per acre, or equal to a cost of $2.45 per ton of cane, $3.60, per barrel of syrup, or 11 cents per gallon of syrup, if the yield is 22 tons of cane per acre. He estimates the cost of manufacturing the syrup from the cane (in 1917) to be approximately 11 cents per gallon in small plants and 10 cents per gallon on a factory scale. Growing the cane and making the syrup, therefore, cost not less than 21 cents

per gallon of syrup produced. The average cost at present is considerably in excess of this figure.

Making Syrup.—Dale states that two general methods of making cane syrup are in use. In one of these the cane is crushed in large sugar cane mills; the resulting juice is clarified by treating with sulfurous acid, addition of lime, settling, and filtering; and the clear juice is concentrated in steam-heated open pans or vacuum pans. The syrup is light in color and of fairly uniform quality. In the second method the cane is pressed in small mills on individual farms and is concentrated in direct-fired sorghum pans. The resulting product is not uniform in quality and much of it is inferior.

Dale and Hudson recommend filtration of the raw juice through a filter press after boiling with infusorial earth (10 lb. to the juice from 1 ton of cane) and concentration *in vacuo*. This yields a syrup superior in appearance and flavor to that obtained by other methods.

SYRUP FROM SWEET POTATOES

Oversize, blemished, and misshapen sweet potatoes, according to Gore, often represent 40 per cent or more of the total crop and are usually allowed to go to waste. He has developed a relatively simple process for converting them into a palatable table syrup.

Blanching.—The sorted and trimmed potatoes are boiled in three changes of water to remove soluble materials from the skins which would otherwise injure the flavor and color of the syrup.

Cooking.—The blanched potatoes are then boiled in water or steamed until soft in order to gelatinize the starch and prepare it for mashing. Water equal to about twice the weight of the potatoes is then added and the potatoes stirred until thoroughly broken up and mixed with the water.

Mashing.—The temperature of the mixture is then brought to 140°F. and about 1 per cent of finely ground pale barley malt free from sprouts is added and thoroughly mixed with the potatoes. The "mash" is held at 125 to 145°F. (preferably 140°F.) until a drop of filtrate from the mash fails to give a blue coloration when mixed with dilute iodine solution. The mashing period is 20 min. to 1 hr.

The diastase of the barley malt during the mashing process converts the starch of the potatoes into maltose, according to the following reaction:

$$\underset{\text{starch}}{(C_6H_{10}O_5)x} + H_2O + \text{diastase} = \underset{\text{maltose}}{xC_{12}H_{22}O_{11}}$$

Dextrins are obtained as intermediate products and the saccharified mash contains a small amount of dextrin.

Pressing.—The wort (sweet liquor) is separated from the pomace by pressing in a rack and cloth fruit press.

Clearing the Wort.—The wort may be boiled and filtered in a filter press with infusorial earth.

Concentration.—The juice may be concentrated in any one of the syrup-concentrating devices described earlier in this chapter.

Refining.—Frequently the syrup possesses an "off flavor." In such cases the partially concentrated syrup should be mixed with a small amount of bone black or vegetable filter char and about 3 per cent of its weight of infusorial earth, boiled a short time and filtered. A syrup of neutral flavor may then be prepared by concentrating the refined syrup to the desired density.

Yield.—The yield of syrup is equal to about one-third the weight of the raw potatoes used.

Character of the Syrup.—If properly prepared the syrup is of light amber color and of mild but characteristic flavor.

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CHAPTER XVII

JELLIES AND MARMALADES

The manufacture of jellies and marmalades is one of the oldest and most important of the fruit products industries and affords a means of utilizing a large amount of sound cull fruit unsuited to other purposes.

DEFINITIONS

Jelly.—Jelly is prepared by boiling fruit with or without water, expressing and straining the juice, adding sugar (sucrose), and concentrating to such consistency that gelatinization takes place on cooling. A perfect jelly is clear, sparkling, transparent, and of attractive color. When removed from the glass, it should retain its form and should quiver, not flow. It should not be syrupy, sticky, or gummy and should retain the flavor and aroma of the original fruit. When cut it should be tender and yet so firm that a sharp edge and smooth, sparkling cut surface remain.

Marmalade.—A true fruit marmalade is a clear jelly in which are suspended slices of fruit or peel. Frequently jams are mislabeled as marmalades.

CONSTITUENTS OF JELLY

Three substances are essential to the preparation of a fruit jelly. These are pectin, acid, and sugar. Of these, pectin is the most important.

Pectin.—It is possible to make a jelly of excellent consistency by combining pectin, acid, sugar, and distilled water in the proper proportions. Fruit juices which are normally deficient in pectin or acid, or both, will make good jelly if these constituents are added. More will be said of pectin later in this chapter.

Acid.—Acid is a necessary constituent of fruit jellies. Juices that are deficient in acidity will make good jelly if citric, tartaric, or other suitable acid is added, provided the proper proportions of pectin and sugar are present. The effect of various concentrations of acid on the jelling point will be discussed later.

Sugar.—Sugar, the third necessary constituent of fruit jellies, may be in the form of any readily soluble sugar, such as cane sugar, dextrose, levulose, maltose, etc. Jelly forms when the concentration of the water-sugar-acid-pectin mixture attains a certain minimum value, which is dependent within limits on the proportions of pectin, acid, and sugar.

Thus Lal Singh in this laboratory in 1921 obtained a jelly at a concentration of 50 per cent cane sugar at 3.05 per cent citric acid and 1.5 per cent pectin; whereas 61.5 per cent sugar was necessary at the finishing point with 0.30 per cent citric acid and 1.5 per cent pectin. See Fig. 63 for the effect of acidity and pectin concentration on sugar concentration at the jellying point.

NATURE OF JELLY

It is probable that the formation of jelly from pectin, acid, and sugar is not a definite stable chemical compound, because if fruit jelly is diluted with warm water the constituents go into solution and can be separated by suitable physical means. Pectin recovered in this manner experimentally has been used in making jelly by again heating it with sugar, acid, and water. This finding tends to disprove Fremy's belief that jelly formation is due to the hydrolysis of pectin to pectic acid by the action of heat and acid. Pectin solutions heated a short time with alkali and then acidified form gels, owing to separation of hydrated pectic acid.

Jelly formation is a colloid phenomenon influenced by pectin concentration, constitution of the pectin, hydrogen-ion concentration, and sugar concentration.

One plausible explanation of pectin gel formation considers it a precipitation phenomenon rather than a phenomenon dependent on swelling of a colloid, pectin. According to this explanation pectin is precipitated by the added sugar, which disturbs the equilibrium previously existing between the water, and the pectin. The pectin is precipitated, not in the anhydrous condition, but as a hydrated colloid which forms a network of fibrils throughout the mass, binding the sugar syrup into a gel. The jelly strength depends on the concentration of the pectin, since obviously with little pectin the network cannot be so dense as with higher concentrations.

Also the more concentrated the sugar solution the less water there is for the jelly to support and therefore the stiffer the texture. Acid causes the jelly to be firmer probably by toughening the fibrils. If the acidity is too low the fibrils are too weak to support the interfibrillar syrup adequately; consequently the jelly is weak. On the other hand if the acidity is too high the jelly "weeps" and may become syrupy. One theory for this phenomenon is that too high acidity causes the fibrils to be too inelastic to maintain the gel structure; another is that it may cause excessive dehydration of the pectin. The texture of pectin is also affected materially by certain salts.

More will be said in following paragraphs concerning the roles of pH value (active acidity), nature of the pectin, sugar concentration, pectin concentration, and the presence of certain salts.

PECTIN AND RELATED COMPOUNDS

Since pectin is such an important constituent of jellies, it is desirable that some attention be given the chemical and physical properties of it and its related compounds.

Definitions.—A committee of the American Chemical Society in 1927 defined pectic substances as follows: Pectin includes the methylated substances useful in making jelly. Protopectin is the parent substance from which pectin is derived. Pectic acids are the substances formed on complete demethylation and complete or partial carboxylation of pectin.

Protopectin.—The insoluble precursor of pectin is now generally termed protopectin. It was called pectose by Fremy, who was first to recognize it in plant tissues. It is also known by the name pectocellulose, although Sucharipa has obtained data that indicate that a pectocellulose existing in the peel of citrus fruits is an actual pectic compound of cellulose, differing from protopectin in resistance to hydrolysis by acids plus heat. Bigelow had previously suggested the existence of pectocellulose. Therefore, it may be that there are present in plant tissues, not only water-soluble pectin, insoluble pectic acid, and protopectin (or pectose), but also a compound of a pectic substance and cellulose. The middle lamellae of cells consist of protopectin and possibly to some extent of the pectocellulose of Sucharipa. On boiling fruits with dilute acid, as in jelly making, the insoluble protopectin is hydrolyzed to soluble pectin.

Protopectin is abundant in green fruits that have attained full size. During subsequent ripening it is hydrolyzed by enzyme action to pectin and during rotting or overripening much of the pectin may be further decomposed to form methyl alcohol and insoluble pectic acid. Since protopectin is the binding substance between the cells, its conversion to soluble pectin results in loosening of the bond between cells with resultant softening of the fruit tissues. Undoubtedly other changes that cause softening also occur during ripening. The change from protopectin to pectin in plant tissues can be followed microscopically by use of stains, particularly by the use of ruthenium red.

Haas and Hill classify the pectic bodies in relation to other carbohydrates as follows:

Monosaccharides....	Pentoses ($C_5H_{10}O_5$) arabinose, xylose, rhamnose, etc. Hexoses ($C_6H_{12}O_6$) dextrose, levulose, mannose, galactose, etc.
Disaccharides......	($C_{12}H_{22}O_{11}$) sucrose, maltose, lactose, etc.
Polysaccharides.....	Starches ($C_6H_{10}O_5$) starch, dextrin, inulin, glycogen, galactosans, including galactan and paragalactan Gums ($C_5H_8O_4$) (a) arabin, cerosin, pentosans (b) mucilages, pectic bodies Celluloses ($C_6H_{10}O_5$)

Gums, when hydrolyzed, yield galactose and pentoses, such as xylose and arabinose. Pectose, when hydrolyzed, yields pectin and, if the hydrolysis is continued, pectic acid, galacturonic acid, and methyl alcohol.

Composition of Pectin.—In defining pectin we refer to those bodies in fruit juices which go into colloidal solution in water and are derived from pectose (protopectin) by ripening processes or other form of hydrolysis. Under certain conditions in the presence of the proper proportions of sugar and acid, they will form jelly.

Preparation.—According to Von Fellenberg one of the best methods of preparing pure pectin for laboratory study is that of Bourquellot and Herissy, in which fruit rich in pectin is boiled repeatedly under a reflux condenser with ethyl alcohol until sugars and other substances soluble in alcohol are extracted. Boiling with alcohol also results in hydrolysis of most of the protopectin to pectin. The alcohol-extracted pulp is boiled with water and pressed. The liquid so obtained is filtered and treated with twice its volume of alcohol to precipitate the pectin, which can be redissolved in water and reprecipitated with alcohol and dried.

Von Fellenberg found that pectins from different fruits vary considerably in composition, but that they are made up of the same basic groupings: pentoses, methyl pentoses, carboxyl radicals, methoxyl groups, and mucic acid-forming groups. In the analysis of orange pectin Von Fellenberg obtained the following results:

Arabinose	41.0%	equivalent to 36.1% araban
Methyl pentose	6.7%	equivalent to 6.1% methyl pentosan
Galactose	54.8%	equivalent to 49.2% galactan
Methyl alcohol	11.5%	equivalent to 11.5% methyl alcohol
Total		102.9%

He explains his high results for total composition to overestimation of the galactose which was computed in terms of mucic acid.

Apple pectin gave approximately 10.54 per cent methyl alcohol and 15.73 per cent arabinose. Swedish turnips yielded pectin containing 8.9 per cent methyl alcohol, currant pectin 9.3 per cent, and quince pectin 10.26 per cent of methyl alcohol.

Methyl alcohol is liberated quantitatively by hydrolysis of the pectin with dilute alkalies, even without heating, and can be estimated by Denige's or Zeizel's methods.

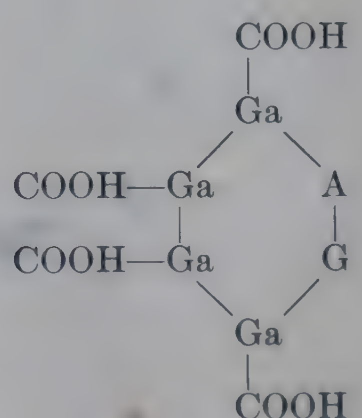
The nature of the methyl pentose grouping is not definitely understood. Tollens believes that there is present in the pectin molecule an esterified carboxyl group, COOH, in place of the CHO or CH_2OH group of the carbohydrate. Thus, pectin would be a methyl ester of pectic acid and hydrolysis of pectin with dilute alkali would be in the nature of saponification. The foregoing represents the earlier information on the chemistry of pectin.

A wide range of combinations of the constituents of pectin is possible, and it is reasonable to assume that there are a number of different pectins in nature, since pectin from different fruits and vegetables varies considerably, not only in its content of CH_3OH, but also in its physical properties and behavior when used for jellies.

More recently Ehrlich identified the substance to which pectin owes its acid properties. This is galacturonic acid, an isomer of glucuronic acid, and a halfway oxidation product between galactose and mucic acid. Its formula is $C_6H_{10}O_7$ or $COH(CHOH)_4COOH$. He was the first also to isolate galactose from the decomposition products of pectin, although its presence had been inferred earlier by others, owing to the fact that pectin yields mucic acid on severe oxidation. Ehrlich also found magnesium and calcium in his pectin preparations. On the basis of his findings Ehrlich believed pectin to be a complex calcium-magnesium salt of anhydroarabinogalactose methoxytetragalacturonic acid. He stated that the arabinose is loosely bound and easily split off by hydrolysis but that the galactose is very tightly bound. He regarded pectic acid as the product remaining after the calcium, magnesium, and araban had been split off. It still contains the galactose group. It would therefore be a galactose galacturonic acid. Von Fellenberg's and Ehrlich's views are not so divergent as they would at first appear since Ehrlich's "ester acid," according to Dore, has about the same characteristics as Von Fellenberg's partially methoxylated ester.

Sucharipa believed that the number of methoxy groups present in the pectin molecule affects the jellying power of the pectin. Pectin of lower methoxy content, he states, is also of lower jellying power. The maximum is eight methoxy groups. Morris states that the formation of pectic acid consists in the replacement in stages of the methoxy groups by carboxyl groups. The pectin from beet roots differs from that from fruits in that it contains an acetyl group. Naturally occurring pectins may differ in their methoxy content and in their jellying power.

Nanji, Patton, and Ling represent the molecule of pectic acid as shown in the following diagram:



In the diagram A represents arabinose, G galactose, and Ga galacturonic acid. Norris and Schryver suggest that pectin is pectic acid with three of the carboxyl groups esterified by methyl alcohol.

At any rate it is now well recognized that galacturonic acid is formed on severe acid hydrolysis of pectin or pectic acid. On the basis of this fact pectin may be determined quantitatively as follows: It is first converted into pectic acid by hydrolysis with alkali, followed by precipitation with acid. The pectic acid is then heated in a flask with 12 per cent hydrochloric acid. The carbon dioxide evolved is collected in a Geissler bulb in strong potassium hydroxide or in standard barium hydroxide and determined by weighing the bulb or titrating the excess barium hydroxide. Dore uses the former method very successfully.

Enzymes, present in fruits in insoluble form and—in certain roots—in soluble form, have the property of hydrolyzing pectin to pectic acid and alcohol. An enzyme capable of bringing about this reaction is known as pectinase.

Methyl alcohol may be demonstrated in apples that are covered with paraffin and allowed to stand at 35°C. for a few days and the same is true of apples placed in water containing toluene. Fruit which has become over-ripe and begun to decay also contains methyl alcohol. These facts confirm the presence of pectinase in fruits.

Pectin, as previously stated, yields, on hydrolysis with dilute alkalies, pectic acid which can be precipitated from solutions in which hydrolysis has taken place, by the addition of a mineral acid.

Hydrolysis of apple pectin yields about 95.17 per cent pectic acid and of orange pectin about 94.8 per cent. During saponification the $COCH_3$ grouping is changed to COOH, which causes an increase in weight, approximately equivalent to the difference in the methyl alcohol yield actually obtained and that found by subtracting the per cent of pectic acid obtained from 100.

Pectic acid is a white powder, if pure, fairly soluble in water and forms a clearer solution than does pectin. It will conduct an electric current and is sour in taste.

Small amounts of electrolytes cause coagulation of pectic acid solutions.

Univalent cations are less active than divalent, and divalent in turn are less active than trivalent cations. The differences in precipitation value of these salts are of the same order of magnitude as those for the precipitation of colloidal sulfides.

Pectic acid is precipitated quantitatively as calcium pectate, and this fact is made use of in one method of analyzing pectin solutions.

The relation of pectic acid, pectin, and protopectin is shown by the following diagram:

Protopectin ⟶ Pectin (pectic acid methyl ester)

By ripening, boiling in water, alcohol, and dilute acids

By pectinase, especially by rotting of fruit; or by NaOH, $Ca(OH)_2$, and $Ba(OH)_2$

By sodium hydroxide, cold

Pectic acid and methyl alcohol

In the above diagram the pectic acid methyl ester of Von Fellenberg is an intermediate product between pectin and pectic acid. Branfoot considers that there is a series of these intermediate products, which are designated as pectinic acids.

Physical Properties of Pectin.—Pectin is a reversible colloid, *i.e.*, it may be dissolved in water, precipitated, dried, and redissolved without alteration of its physical properties.

On the addition of water to dry pectin, paste-like lumps are first formed. These finally go into solution, but solution is greatly hastened by heating the mixture and by adding sugar. A solution clear by transmitted, but cloudy by reflected, light is obtained.

Under the ultramicroscope there will be found in this solution numerous particles in lively motion. These particles vary in size but are (ultramicroscopically considered) small.

In addition to alcohol, several metallic salts have the power of precipitating pectin, and at one time it was considered that the precipitates of pectin with metallic salts were definite chemical compounds. Analyses of the precipitates give varying ratios of salt to pectin, and the present conception of the precipitation is that it is an electrolytic coagulation similar to that which occurs with many other colloids when suitable electrolytes are added.

Preparation of Commercial Pectin.—Cull apples, waste apple peels and cores, and cull citrus fruits are the usual sources of commercial pectin. This product now has become an important item of commerce and is widely used in the making of jelly. A pectin syrup (Certo) is in common use for preparing jelly in the home. Pectin for commercial use is in powdered form.

Alcohol Precipitation.—In 1913 P. R. Boyles was granted a patent upon a process for the preparation of pectin by extraction of the pectin by boiling with water, concentration of the resulting solution by boiling, and precipitation of the pectin from the concentrated solution by the addition of ethyl alcohol. The principal objection to the precipitation of pectin with alcohol is the difficulty of recovering all the alcohol.

Waksman states that in the preparation of a pectin concentrate from apples, the apple pulp (usually dried pomace) is diffused with cold water to extract most of the acid and sugar. The cold water does not dissolve

any appreciable proportion of the pectin. The residue after water extraction is then boiled 35 to 40 min. with water containing a small amount (about 0.1 per cent) of tartaric acid. The juice is pressed from the heated pulp and cooled.

A small amount, 1½ to 3 oz. per 100 lb. of extract, of diastasic enzyme from a mold of the aspergillus group (Taka diastase) is added, and the mixture is maintained at 45 to 50°C. (110 to 120°F.) to hydrolyze the starch in solution and thus prevent starch "haze" in jelly made from the pectin extract.

After hydrolysis the solution is filtered and is then concentrated *in vacuo* to a thick syrup, which is preserved by sterilization in bottles. Cans have also been used as containers for pectin concentrates, although there is danger of perforation of the tin plate.

Magoon and Caldwell have described a process in which pectin is precipitated by mineral salts. Apple or other fruit pulp is boiled with several changes of water. The combined extracts are treated with a small quantity of saturated commercial alum solution with constant stirring; ammonium hydroxide is then added in slight excess of neutrality; and the solution is warmed to coagulate a voluminous precipitate which forms on addition of the alum and ammonia. The liquid is then filtered and magnesium sulfate in crystalline form is added at the boiling point, the additions and boiling being continued until a precipitate no longer forms. The precipitate of pectin is separated by filtration and is washed with cold water to remove occluded salts. The washed pectin can then be dried and will retain its jellying power indefinitely. In practice it is difficult to remove the salts completely.

In the method developed by several members of the research staff of the Exchange Lemon Products Co. and Exchange Orange Products Co. (Taylor, Wilson, Jamieson, and others) citrus peels are heated quickly to destroy enzymes that hydrolyze pectin. The ground peel is then extracted at 80 to 90°C. in water acidified with sulfur dioxide. The extract is filtered and made slightly alkaline with ammonium hydroxide. Sufficient aluminum sulfate is then added to render the solution slightly acid. The aluminum hydroxide formed precipitates the pectin. The precipitate may be washed, filtered, pressed and dried, and the aluminum hydroxide may be dissolved from it with alcohol acidified with hydrochloric acid. For further details see *U. S. Public Service Patent* No. 1,497,884, June 17, 1924 by Taylor, Jamieson and Wilson.

SUITABILITY OF VARIOUS FRUITS FOR JELLY

Fruits for jelly should contain sufficient acid and pectin to yield a good jelly without the addition of these substances; although often in commercial practice this ideal is not attained. Some fruits contain

enough of both pectin and acid for the purpose; some are deficient in one or the other, and some are deficient in both substances.

Of the fruits rich in pectin and acid, crab apples, acid varieties of table apples, loganberries, sour blackberries, currants, lemons, limes, grapefruit, sour varieties of oranges, sour varieties of guavas, Damson plums, most other varieties of four plums, Labrusca varieties of grapes, sour varieties of cherries, cranberries, and roselle are good examples. Of fruits and vegetables low in acid but rich in pectin, the following may be cited: sweet varieties of cherries, unripe figs, pie melon, carrots, unripe bananas, and ripe quinces. Fruits and vegetables that are rich in acid but low in pectin are apricots, rhubarb, and most varieties of strawberries. Fruits which may be classed as containing a moderate concentration of both acid and pectin are ripe Vinifera varieties of grapes, ripe blackberries, ripe apples, loquats, and feijoas. Fruits low in both acid and pectin are represented by pomegranates (arals), ripe peaches, ripe figs, and ripe Bartlett pears.

It is customary to blend fruits deficient in acid or pectin, or both, with fruits which have an abundance of the required constituents.

Because it possesses no appreciable flavor of its own, commercially prepared pectin is coming into more general use for the purpose of enriching juices of fruits deficient in this component.

THE PREPARATION OF JELLY

The process of jelly making may be discussed conveniently under several operations, *viz.:* those of boiling the fruit, extraction of the juice, clearing the juice, adding the sugar, boiling, packaging and sterilizing.

Boiling the Fruit.—Most fruits should be boiled for extraction of the juice in order to obtain the maximum yield of juice and pectin, because boiling converts pectose into pectin and softens the fruit tissue.

Very juicy fruits, such as berries, do not require the addition of water and need only be crushed and heated to the boiling point for 2 or 3 min. For most berries the shorter the period of boiling the better the flavor of the resulting jelly. Firm fruits, such as apples and oranges, are cut or crushed and require the addition of water. Citrus fruits are cut in pieces about ⅛ to ¼ in. in thickness.

The length of boiling will vary according to the variety and texture of the fruit. Apples normally require only 20 min. or less and oranges from 30 to 60 min. The fruit should be heated only long enough to soften it sufficiently to permit thorough extraction of the juice by pressing and not long enough to render it "mushy." Fruit which is boiled too long yields a cloudy juice which is very difficult to filter. Boiling converts much of the insoluble protopectin into soluble pectin.

Amount of Added Water.—The amount of water that should be added to the fruit should be sufficient only to obtain a good yield of juice and pectin. Juicy fruits require no water; apples from ½ to an equal volume of water; and citrus fruits, because of the long period of boiling necessary, usually require from 2 to 3 volumes of water for each volume of sliced or crushed fruit. If too much water is used the resulting juice will be too dilute and will require an undue amount of concentrating before jelly can be made from it; if too little water is used there is danger of scorching the fruit or of obtaining a low yield of juice and jelly. Fruits very rich in pectin, such as currants, loganberries, cranberries, lemons,

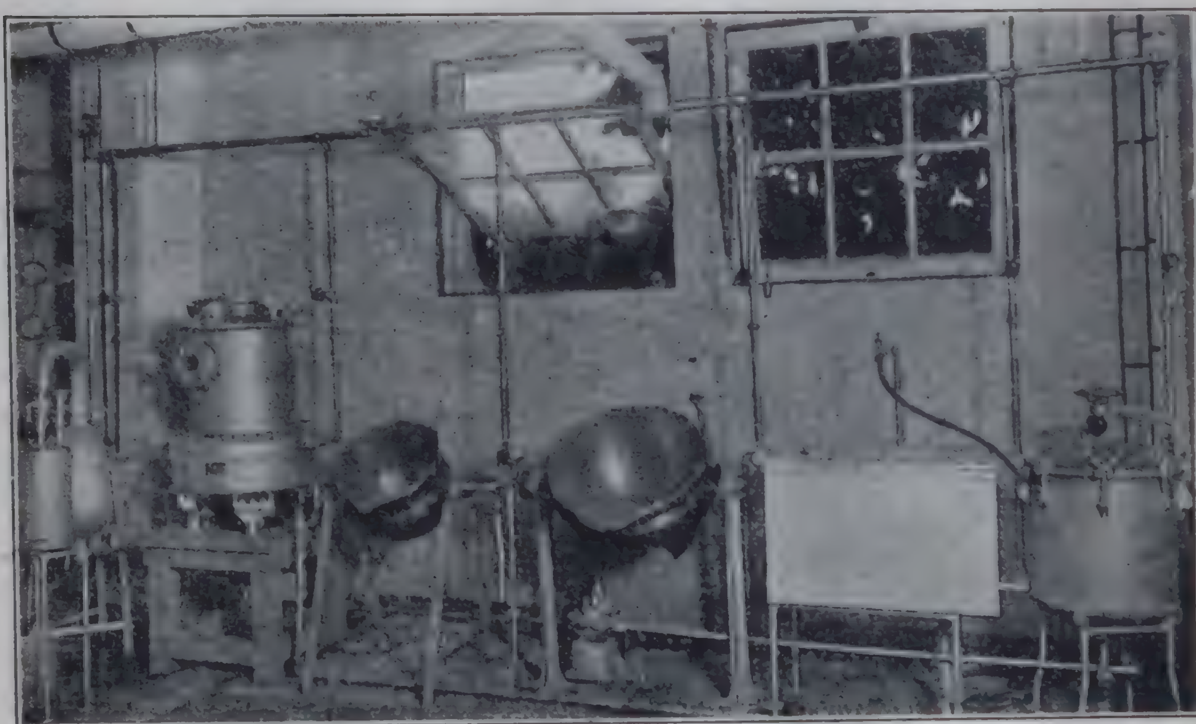


FIG. 61.—Tilting jelly kettles. (*In Fruit Products Laboratory, University of California, Berkeley, Calif.*)

and Labrusca (eastern) varieties of grapes, can be extracted to advantage with two or more succeeding lots of water. Frozen-pack berries and plums used for jelly making are handled in much the same manner as the fresh fruits. They should be dumped into the required amount of boiling water while the fruit is still in the frozen condition (see Chap. XXXI).

Kettles.—The extraction of juice from fruits for the preparation of jelly on a commercial scale is usually accomplished by the use of steam-jacketed copper kettles, placed on a platform or a floor above the press so that the cooked pulp and juice may be drawn from the kettle by gravity to the press. If a large kettle (50 or more gallons' capacity) is used, it should be fitted with a large valve (2 in. or larger) to permit drawing off of the fruit. If the installation is of small size, a tilting kettle is most convenient.

Effect of Various Metals.—Copper and tin injure the color of fruits if contact at the boiling point is prolonged, hence aluminum is to be preferred for most fruits. Glass-lined equipment is least liable to cause injury to the color of fruits and should be used for the boiling of citrus and other fruits which may require a long period of boiling. Silver-plated steam coils can be used in steam-jacketed glass-lined kettles to increase the rate of heating. The principal objection to steam-jacketed glass-lined equipment is its slow conductance of heat, because of the thickness of the walls. Stainless-steel, nickel and monel metals are satisfactory, although costly.

Pressing.—The housewife, in preparing juice for jelly making, usually does not press the fruit; she merely places the heated pulp and juice in a cloth jelly bag and allows it to drain, in order to obtain a clear juice.

In the jelly factory a high yield of jelly juice rich in pectin and obtained with a minimum of handling is desired. The use of the rack and cloth press has been found in practice to be one of the most desirable means of pressing the juice from the boiled pulp. The hot fruit and juice direct from the kettle are placed in the cloths of the press and pressed as described in Chap. XV.

Use of Pomace.—The press cake may, if desired, be mixed with water in the kettle and heated a second time to obtain the remaining pectin. This is probably not advisable for cheap fruits, such as apple culls and apple waste or citrus fruit culls, but may become profitable with more costly fruits, such as currants, loganberries, etc.

The press cake (pomace) has some value as stock food and can be fed direct, or it can be dried, stored, and used as needed. It has very little fertilizing value but can be used to improve the texture of heavy soils if mixed with lime in order to prevent formation of harmful concentrations of acid in the soil.

Clearing the Juice.—Jelly is most attractive when clear, and most jelly factories now use mechanical filters.

Filtration.—In the Fruit Products Factory at the University of California a small pulp filter is used successfully, as described in Chap. XV. Filtration is rapid, the filtered juice is fairly clear, and second filtration renders the juice brilliantly clear. This same type of filter is utilized upon a large scale in many commercial jelly factories.

Filter presses can also be used. The juice is mixed with infusorial earth before filtration. If from $\frac{1}{10}$ to 1 per cent of a good grade of the earth is mixed with the juice, filtration is fairly satisfactory. The earth forms a filtering layer on the press cloths and thereby reduces sliming or clogging. Well-known filter earths are Filter-Cel and Dicalite, both obtainable in various grades.

For the small jelly factory, heavy cloth jelly bags can be used to improve the clearness of the juice, although it is usually not possible to obtain a brilliantly clear jelly by their use. If a filter aid such as Hy-Flo or Dicalite is added filter bags yield a clear juice.

Filtration must be accomplished before the addition of sugar, because the latter so increases the viscosity of the juice that filtration becomes extremely slow or impossible. If the juice requires concentration by boiling before the addition of sugar, this should be done before filtering, since boiling causes precipitation of organic matter (probably protein), which should be removed by filtration or other means before sugar is added.

Settling.—Some fruit juices can be satisfactorily cleared by settling overnight in vessels 1 to 3 ft. in depth. Shallow tanks should be used because of the relatively slow rate of settling of juices from boiled fruits.

Finings.—Numerous experiments have been made (Cruess and McNair) upon the clearing of jelly juices by the use of finings, but none of the ordinary finings were very satisfactory, although bentonite and certain kaolin clays give fair clarification.

Centrifuging.—Recently, experiments with centrifugal clarifiers have proved that jelly juices can be satisfactorily clarified by centrifuging at a high speed, both the Sharpless and De Laval clarifiers being used successfully for the purpose. As much of the coarse pulp as possible should be removed before centrifugal clarification, in order to avoid too rapid clogging of the bowl of the clarifier. This method is rapid and inexpensive in operation and deserves more serious study and attention from jelly manufacturers.

Addition of Sugar.—The housewife usually guesses at the amount of sugar that her jelly juice will require, and to juices that she believes rich in pectin she adds an equal or greater volume of sugar, and to juices that she has found by experience to be of poor quality for jelly, less than an equal volume of sugar. Many jelly makers proceed on this same basis. Very valuable information can be secured by boiling 200-cc. portions of the juice with 100-, 150-, and 200-gram portions of sugar in a small stew pan and pouring into jelly glasses to cool.

Pectin Test.—A simple and very useful test to determine the proper proportion of sugar to use is the pectin-and-alcohol test, in which a spoonful of the juice and a spoonful of 95 per cent grain alcohol (denatured alcohol will serve the purpose) are mixed in a tumbler. A juice rich in pectin forms a jelly-like mass, one of medium pectin content several large lumps of jelly-like material, and one poor in pectin forms a few small pieces of stringy precipitate or no precipitate whatsoever. From the results of this test one can intelligently judge the amount of sugar that

may be added to the juice. Thus to a juice containing a large amount of pectin may be added at least 1 cup of sugar per cup of juice; to that of medium pectin content usually ½ to ⅔ cup of sugar per cup of juice, while the juice containing a small amount of pectin must usually be concentrated by boiling until it will give a satisfactory pectin test. The principal cause of failure in jelly making is the addition of too much sugar. Too large an addition of sugar so dilutes the pectin that jelly will not form. Therefore, the lower the pectin content of the juice the smaller the proportion of sugar should be.

The test must be standardized by experiment against factory practice, since the test at best is only relative, but when so standardized, it becomes a valuable means of factory control. The viscosity of the juice varies with the pectin content. Therefore a viscosity test by any standard method may be used as a guide in addition of sugar.

Acid Determination.—The acidity of the juice is nearly as important as its pectin content. Titration of a 10-cc. sample of the juice with N/10 sodium hydroxide, using phenolphthalein indicator, is a satisfactory means of determining the acidity. It is generally necessary to dilute the sample with about 100 cc. of distilled water, in order to make observation of the end point accurately. The acidity of the juice should be such that the finished jelly will contain at least 0.5 per cent total acidity, but preferably 0.75 to 1 per cent. Juices of low acidity can be made into jelly without increasing the acidity, but an excessive amount of sugar or boiling will be necessary. It is usually more economical to increase the acidity of such juices by the addition of citric or tartaric acid or by the addition of a juice of high acidity. As stated later, pH value is the real factor involved, when one speaks of the relation of acidity to jelly formation.

The sugar should be weighed carefully, and the volume of the juice accurately measured. If the volume of the kettle is known, it can be filled to a given height, and actual measurement of the juice avoided. Measurement of the sugar by weight rather than by volume is desirable because of the greater accuracy of the former method.

It is not necessary to heat the sugar before it is added. It must be stirred with the juice in the kettle to avoid sticking and burning. High-quality beet sugar is equally as good for jelly making as is cane sugar.

Boiling.—Boiling is one of the most important steps in the jelly making process, as it dissolves the sugar and causes union of the sugar, acid, and pectin to form jelly. It usually causes a coagulation of certain organic compounds which can be skimmed from the surface during boiling, and their removal renders the jelly clearer. Its principal purpose is to increase the concentration of the sugar to the point where jelling will occur.

The boiling operation, while normally a necessary step in jelly making, should be as short as possible. Prolonged boiling results in loss of flavor, injury to color, and hydrolysis of the pectin; consequently it is a frequent cause of jelly failure.

Kettles.—Boiling in commercial practice is usually conducted in open steam-jacketed, copper kettles which may or may not be lined with tin or silver. Stainless steel, nickel, monel metal, and aluminum are preferable to tin, copper, or silver, as they affect color and flavor less. Large kettles are less desirable than small ones, for the reason that the boiling process must be unduly prolonged in the larger vessels with consequent injury to flavor and color. Therefore, 25- and 10-gal. kettles are to be preferred to 50- or 110-gal kettles. Boiling the juice in small lots permits more rapid boiling without danger of loss by frothing than is the case when the kettle is filled to capacity.

Skimming.—During boiling the juice should be skimmed if necessary in order to remove coagulated material and should be stirred to cause thorough mixing.

End Point.—The boiling is continued until on cooling the product will form a jelly of the desired consistency. The concentration of the mixture when this point is reached will depend upon several factors, *viz.*, the concentration of pectin, the concentration of acid, the ratio of sugar to pectin and acid, and the texture desired. If the jelly is to be shipped long distances and subjected to rough handling, it must be stiffer than if it is to be stored on the pantry shelf at once or to be delivered to local dealers. In general, the finished product should be of the consistency described in the definition of jelly at the beginning of this chapter.

The most common method of determining the end point is by allowing the liquid to sheet from a wooden paddle or from a large cooking spoon. If it drips from the instrument as a thin syrup, the process is not complete; if it partly congeals and breaks from the paddle or spoon in sheets or forms jelly-like sheets on the side of the paddle or spoon, the boiling is considered to be complete. The sheeting test is, however, subject to error because of the personal equation and because of variation in behavior of different lots of juice.

A more accurate method of determining the jelling point is by the use of a thermometer inserted in the boiling juice. If the juice contains the proper proportions of sugar, acid, and pectin, the boiling point of the liquid at the jelling point will normally be about 8 to 9°F. above the boiling point of water. At sea level this will be at 220 to 221°F. and corresponds to a concentration of 65 to 70 per cent total solids in the jelly after cooling. It is also possible to use a hydrometer test on the hot liquid in order to judge the end point. A Balling or Brix hydrometer is suitable for the purpose, but if the test is made on the juice near the

boiling point, the Balling or Brix degree should be approximately 58 to 60°, corresponding to about 65 to 67° Brix or Balling at room temperature. The thermometer and hydrometer tests should be confirmed by the sheeting test, since the juice may be so poor in pectin or acid that jellying will not occur until a greater concentration is reached than that given above, or it may be so rich in these constituents that the jellying point is reached before a concentration of 65° Balling is reached. Many jelly manufacturers now use an Abbe retractometer for determining the finishing point. A drop or two of the liquid is placed on the prism of the instrument which is cooled by a water jacket. The refractive index may then be read in a few seconds and the corresponding soluble solids content obtained from a table such as that in the Association of Official Agricultural Chemists "Official and Tentative Methods of Analysis."

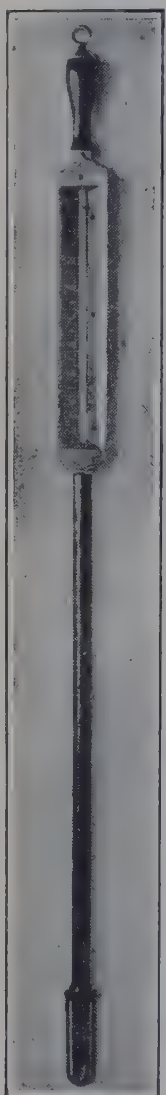


Fig. 62.—Jelly thermometer for use in large jelly kettles.

If the jelly is to be preserved by pasteurization, the final concentration need not be so great as when the product is preserved by a high concentration of sugar. The housewife usually relies upon high sugar concentration to preserve her jelly, while the commercial manufacturer usually pasteurizes his product in hermetically sealed containers.

Flavor Changes.—Experiments (Cruess and McNair) indicate that the changes in flavor that take place during the boiling of jelly are brought about both by loss of flavor through evaporation and by hydrolysis or other form of decomposition.

Hydrolysis of Sugar and Pectin.—Boiling of the sugar solution in the presence of the fruit acid results in inversion of some of the cane sugar to dextrose and levulose. For this reason a jelly which is boiled for a long period is less liable to develop crystals of sucrose (cane sugar) than is a jelly boiled a short time, assuming that the jelly in both cases is concentrated to the same point.

Pectin is also hydrolyzed by unduly prolonged boiling, and the liquid may fail to gel under such a condition.

Relation of Pectin and Acid to Jelling Point.—It was stated above that the end point of the boiling process depends upon the concentration of acid and pectin present in the original juice. Lal Singh, working in the writer's laboratory, has studied quantitatively the relatoin of acidity to the jelling point of citrus fruit juice.

He used dried pectin from oranges, prepared by Bourquellot and Herissy's method, citric acid crystals, distilled water, and cane sugar. A constant amount of pectin, 1.5 grams, was used in each test. The

acidity was varied from 0.12 to 4.05 per cent, based on the finished product, and the proportion of sugar was also varied. An excess of water was used to dissolve the pectin, sugar, and acid. The mixture was then concentrated by boiling to exactly 100 grams. The various samples were sealed in jelly glasses, stored, and later examined to determine the sugar concentration at which jelly barely formed with a given acidity. The results are given in Table 47 and Fig. 63.

It will be noted that at 0.12 per cent acidity (as citric) 75 grams of sugar per 100 grams of jelly were necessary to form jelly; while at 1.05 per cent acidity jelly formed when the finished product contained only 53½ grams of sugar per 100 grams of jelly. These experiments prove that a material saving in sugar can be accomplished by increasing the acidity of juices deficient in acid.

TABLE 48.—RELATION OF ACIDITY TO SUGAR CONCENTRATION AT THE GELLING POINT

(*After Lal Singh*)

Lot No.	Amount of acid added	Per cent total acid	Sugar necessary barely to jell, grams	Total weight of jelly, grams
1	None	0.05	75	100
2	0.12	0.17	64	100
3	0.25	0.30	61½	100
4	0.50	0.55	56½	100
5	0.70	0.75	56½	100
6	1.00	1.05	53½	100
7	1.25	1.30	53½	100
8	1.50	1.55	52	100
9	1.70	1.75	52	100
10	2.00	2.05	50½	100
11	2.50	2.55	50½	100
12	3.00	3.05	50	100
13	3.50	3.55	50	100
14	4.00	4.05	50	100

Similar experiments were made to determine the effect of pectin on the jelling point. The data are summarized in Table 49 and Fig. 63.

In general the results resemble those obtained with variation of the acidity. No jelly was obtained at 0.75 per cent pectin, although other investigators have obtained jelly with less than this concentration of lemon pectin; a fact which might indicate that lemon pectin possesses greater jellying power than the pectin used by Lal Singh or more likely that the latter's pectin was not free from impurities. The pectin used by Lal Singh was impure and hence rather high concentrations were required for

TABLE 49.—THE EFFECT OF PECTIN CONCENTRATION ON THE SUGAR CONCENTRATION AT THE JELLING POINT
(After Lal Singh)

Percentage of pectin in finished product	Percentage of sugar present in finished product at lowest sugar concentration for jelling
0.50	No jelly formed at any concentration.
0.75	No jelly formed at any concentration.
0.90	65.0
1.00	62.0
1.25	54.0
1.50	52.0
1.75	51.0
2.00	49.5
2.75	48.0
4.20	45.0
5.50	43.0

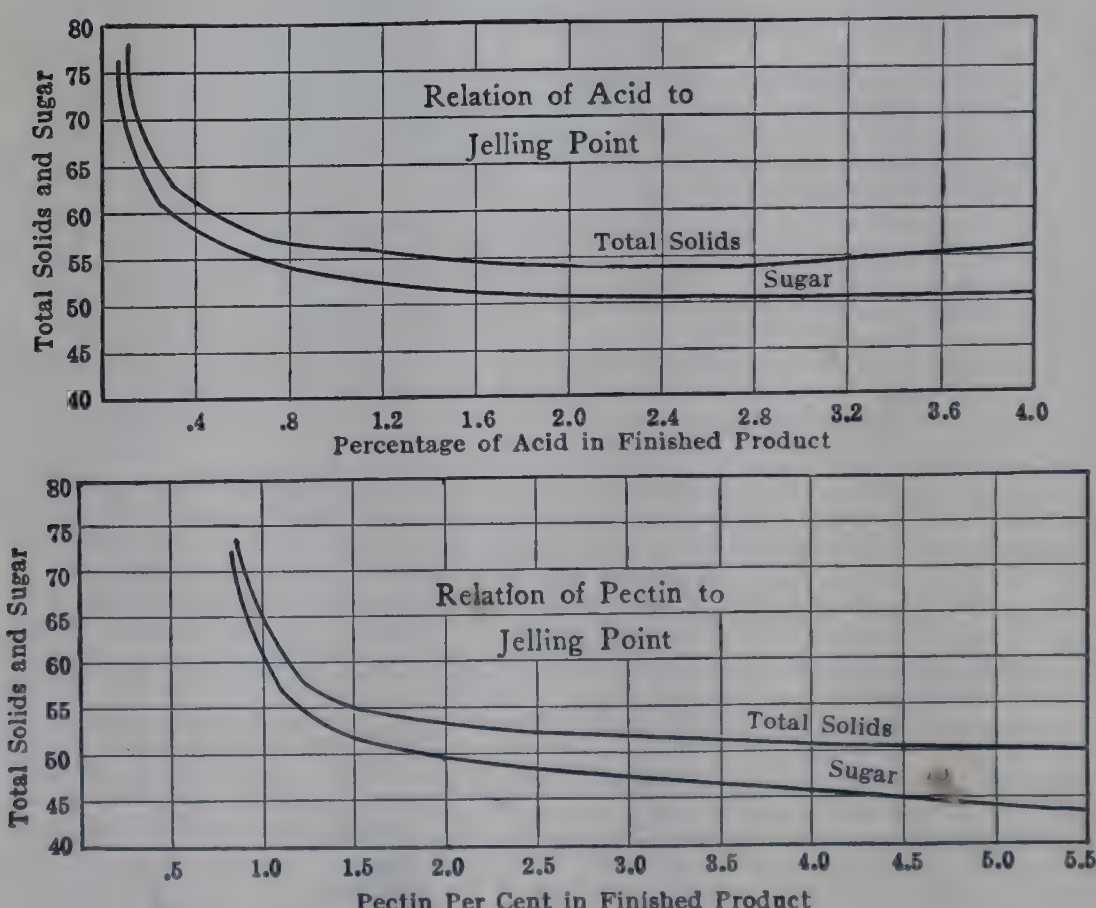


FIG. 63.—Relation of acidity and pectin to jelling point.

jelly formation. Poore obtained a fair jelly at 0.26 per cent pectin when highly purified citrus pectin was used.

Relation of Hydrogen-ion Concentration.—L. W. Tarr of the Delaware Experiment Station has made a series of experiments to determine the effect of the hydrogen-ion concentration on the jellying point of mixtures of pectin, water, sugar, and acid. His conclusions are as follows: (1) The formation of fruit jellies cannot be correlated with the total acidity, because the solution may contain buffer substances which reduce the hydrogen-ion concentration without reducing the total acidity as determined by titration. (2) There is a direct relation between the active acidity, or hydrogen-ion concentration, and the formation of jelly. The minimum hydrogen-ion concentration at which jelly formation occurs is pH 3.46, a value which is independent of the nature of the acid used. (3) The presence of neutral salts probably reduces slightly the minimum hydrogen-ion concentration at which jelly will form. (4) Jelly formation occurs irrespective of the amount of pectin present, once the minimum hydrogen-ion concentration is reached, provided, however, the quantity of pectin present must be equal to the minimum amount necessary to produce jelly. (5) The character of the jelly is also determined by the hydrogen-ion concentration. It becomes stiffer as the hydrogen-ion concentration increases. Syneresis ("weeping") occurs when the hydrogen-ion concentration is greater than a pH of 3.1. (6) There is a stoichiometrical relation between pectin and the combining power of the acids. (7) Tartaric acid is probably the most effective of the acids commonly present in fruit juices and citric the least effective. (8) The hydrogen-ion concentration of fruit juices depends upon the character of the acids present and upon the buffer action exerted by the juice, pectin itself exerting an appreciable buffer action.

Tarr found that many different acids could be used to cause jellying of mixtures of pectin, acid, sugar, and water and in all cases the jelling point could be correlated with the hydrogen-ion concentration as noted above. See also the other papers by Tarr, Baker, and others of the Delaware Experiment Station, in list of references at end of this chapter.

Use of Commercial Pectin.—As previously stated commercial pectin has come into rather widespread use in the making of jelly. Its addition should be declared on the label. It may be used to reinforce the pectin content of juices of normal fruit content, but it may not be used to unduly "stretch" the juice by addition of excessive amounts of water. Seizures of "stretched" pectin jellies by food officials have been rather frequent in some localities and the penalties severe.

Manufacturers of citrus fruit pectin in California and of apple pectin in New York, Missouri, and elsewhere furnish full and detailed directions for the use of their respective products.

Commercial pectins vary in strength and in rate of setting (rate of jellying). The rate of setting may be controlled by the addition of certain buffer salts. These are usually added to the powdered pectin by the pectin manufacturer. Such salts are sodium citrate, sodium sulfate, sodium hydrogen tartrate, disodium hydrogen phosphate, disodium hydrogen citrate, and calcium carbonate. Their presence tends to delay the time of setting, a useful property in some cases, as it permits pouring of the jelly without "graining" caused by partial, premature jelly formation in the kettle. On the other hand a quick setting pectin is desired for use in jams in order to prevent floating of the fruit.

The jellying power of commercial pectins is expressed in terms of pounds of sugar that will be jellied by 1 lb. of pectin. Thus 1 lb. of a "100-grade pectin" will make a satisfactory jelly with 100 lb. of sugar under certain specified conditions such as those given by Wilson (see reference list).

Wilson recommends that the required amount of powdered pectin be mixed with six times its weight of sugar and dissolved in water at 60 to 70°C. The sugar prevents clumping of the pectin. Clumping is less at 60 to 70°C. than at 100°C. because at the higher temperature the sugar dissolves much more rapidly than the pectin, leaving it in suspension to form clumps. The mixture is stirred for several minutes and may then be heated to boiling to complete the dissolving of the pectin.

Another convenient method is that recommended by the Speas Co., which consists in preparing a standard solution of pectin and water as follows: Four pounds of powdered pectin is mixed with 12 lb. of sugar. The mixture is dissolved by sprinkling it into 9 gal. of boiling water with stirring. A mechanical mixer is useful. Turn off the heat and stir until dissolved. Make to 90 lb. This solution contains 4.5 per cent of pectin. If desired, citric acid or tartaric acid may also be added.

Usually, if acid is added to the batch, it is not added until the jelly has been cooked to the desired solids content and just before it is to be poured into the glasses. Acid causes rapid setting of the jelly and, if added too soon, may cause it to jellify before it can be poured.

The amounts of pectin and of acid (if any) to be added are determined by preliminary jelly-making tests with 100 to 500 cc. of the juice. With fruit of uniform quality such tests need not be made very frequently.

The normal procedure in making jelly with use of pectin is to prepare the fruit juice in the usual manner by boiling, pressing, and filtering. A measured volume of the juice is then placed in the kettle, and the amount of pectin determined by small-scale test is mixed with six times its weight of sugar and dissolved in water, as previously described, to give about a 3 to 4 per cent solution. Or a measured volume of $4\frac{1}{2}$ per cent pectin-water solution is taken. It is added to the juice and mixed

by stirring. The required amount of sugar is then added, and the batch is "boiled down" to the finishing point, *i.e.*, to the desired boiling point or desired refractive index. The required amount of acid (if any) as a 25 or 50 per cent solution in water is then stirred in, and the jelly is poured at once into glasses.

Packaging and Preservation.—A wide variety of sizes and shapes of containers is used for jellies. Glass is the usual material out of which they are made, although enamel-lined tin cans and special paper containers are also used.

In the household the jelly is usually poured scalding hot into jelly glasses and sealed with melted paraffin. Infection with yeast or mold with consequent spoilage often ensues when this method is used. It is much safer to seal the scalding hot jelly hermetically in fruit jars or special glasses for home use that may be sealed hermetically, as a paraffin coating is rarely so perfect as to exclude microorganisms.

At one time commercially prepared jellies were preserved very generally by the use of sodium benzoate. Since public sentiment has turned against food products containing preservatives, manufacturers have adopted pasteurization. Jelly preserved by pasteurization need not be concentrated to so high a sugar content as that not so treated, and the saving in sugar may often pay for the added cost of pasteurization.

Filling Machines.—Automatic filling machines which measure a definite volume of jelly into each container are in general use in large factories. They greatly reduce the cost of filling as compared with that of hand filling and give more uniform net contents.

Sealing.—Two types of vacuum-sealed jars are in common use. In one of these the seal between the glass and jar cover is made with a rubber composition ring attached to the cap. This composition melts during pasteurization and after cooling of the jar and contents, solidifies to form an airtight seal. The lid must be held in place with a clamp during pasteurization. The second style of jar is sealed with a rubber gasket similar to a fruit-jar rubber, but this rubber is pressed against the sides of the jar rather than the top. It is held in place by friction, and the cap is rolled in much the same manner as an ordinary sanitary can top. The cap needs no clamp to hold it in place during pasteurization.

Canning.—Small enamel-lined jam cans (No. 1- to 8-oz. size) and gallon cans are sometimes used for jelly, the former size for sale for family use and the latter for bakers' use. Wooden tubs or buckets are often used for cheap jellies for bakers' use, the product usually being preserved with sodium benzoate. If cans are used for jellies made from fruits of red color, the inside of the cans should be heavily lacquered to prevent bleaching of the color by tin salts.

Pasteurizing.—Containers sealed scalding hot, *e.g.*, 185 to 212°F., need not be pasteurized, as the hot jelly itself will sterilize the container. Usually, it is not feasible on a commercial scale to fill all of the containers of a given lot of jelly at such a high temperature, and pasteurization therefore becomes necessary. In some large plants a continuous pasteurizer is used, in which the glasses of jelly are carried by means of a woven wire-cloth conveyer through a tank of water maintained at the pasteurizing temperature. The temperature is held constant by means of a thermostat similar in operation to those described for the regulation of sterilizers for canned foods.

A temperature of 180°F. and a time of 30 min. is usually sufficient. If the jelly is filled hot into the glasses, the pasteurizing time may be shortened; if the glasses are of large size or filled cold, a longer period may become necessary. Heat penetration tests should be made by the manufacturer in order to determine the necessary length of the pasteurizing accurately for each size of container.

Some continuous pasteurizers are equipped with a device for cooling the jars after pasteurization. This may consist of several tanks of progressively decreasing temperature, through which the jars pass, or of a series of sprays of water of progressively decreasing temperature. If allowed to stand hot for several hours, the jelly will be materially injured in flavor and color.

Yields.—The yield of jelly from a given variety of fruit will vary with its maturity and other conditions. Repeated extractions of the pulp will greatly increase the yield of jelly as compared with that obtained by a single extraction. In semicommercial-scale experiments in the Fruit Products Laboratory at the University of California, yields of 350 gal. of jelly per ton from citrus fruits and 300 gal. of jelly per ton from sour berries are not uncommon.

PREPARATION OF MARMALADES

A good marmalade should be a jelly with pieces of fruit suspended therein and should not be merely a jam or butter. The principles of jelly making, therefore, apply also to the preparation of marmalade.

Types of Marmalade.—English and Scotch marmalades are usually made from the bitter varieties of oranges from Spain, grown principally in the vicinity of Seville. In America sweet varieties are used.

English Marmalade.—The fruit from which the English type of marmalade is produced is high in both acid and pectin and no difficulty is experienced in obtaining a firm jelly-like marmalade from it.

The fruit may be shipped in boxes or in bulk to the factories in England, or it may be shipped in barrels in brine or in cans sterilized in sliced or shredded form in its own juice. The last-named method

is successful and probably the most satisfactory. The writer has observed the canning of such shredded fruit at Valencia, Spain, for the British trade.

American Marmalade.—In the United States, marmalade is usually made from cull oranges of the shipping varieties, such as the Navel and Valencia. The product is characterized as "sweet marmalade" as distinguished from the bitter English marmalades. The sweet oranges grown in California and Florida for the fresh market are usually somewhat deficient in acid or pectin, or both, when allowed to ripen thoroughly. It is, therefore, usually desirable to mix grapefruit or lemons with the oranges, in order to furnish pectin and acid. Marmalade in which grapefruit is used is bitter and resembles the English product to a small degree. Those who have been accustomed to the English marmalade prefer the orange-grapefruit type to the orange-lemon type of marmalade, but the average American consumer usually prefers the sweet marmalade.

Deciduous Fruit Marmalades.—Marmalades are also made from other fruits, although many so-called marmalades are jams rather than marmalades. Various sliced fruits can be mixed with a juice rich in pectin and sugar in preparing a true marmalade, *i.e.*, a jelly in which are suspended pieces of fruit. The famous Bar-le-duc of France is essentially a marmalade prepared from currants.

Preparing the Juice for Marmalade.—According to the usual American factory practice in making marmalade, the juice and the sliced fruit are prepared separately and are not mixed until the final boiling of the juice and fruit with sugar.

Slicing.—In preparing a marmalade from oranges and lemons these fruits are mixed in the proportion of about 1 lb. of lemons to 4 to 10 lb. of oranges and sliced about $3/16$ in. thick. Ripe fruit of both varieties is used. In investigations by Lal Singh it was proved that better results are obtained if the ratio of lemons to oranges is increased to equal weights of the two fruits. The flavor is more pleasing and a higher yield of finished product is obtained with this increased proportion of lemons.

Boiling.—The sliced fruit is covered with two to three times its volume of water in a jelly kettle (glass-lined equipment is to be preferred) and the mixture is boiled until the fruit is tender, usually about 1 hr. It is sometimes necessary to add water during boiling to replace that lost by evaporation.

The hot pulp is then pressed in a rack and cloth type of press. Heavy cloths or two thicknesses of ordinary press cloths should be used in order to eliminate as much of the fine fruit pulp as possible.

Filtration.—The juice can be cleared by settling in shallow vessels for 24 hr. or by filtration. Felt or heavy duck bag filters yield a juice

which is opalescent but which, nevertheless, produces a marmalade of satisfactory appearance. By use of a filter press it may also be filtered hot after addition of infusorial earth.

Analysis of Juice.—The juice should be tested for acidity and pectin, should give a good pectin test, and should contain at least 1 per cent of acidity expressed as citric acid. It is possible to use the Balling test as a method of factory control in determining the suitability of the juice for marmalade manufacture. If equal weights of lemons and oranges have been used, the juice should test about 6° Balling at 15.5°C. (60°F.), if it is desired that an equal weight of sugar and juice be used. A viscosity test is also useful. A simple procedure consists in noting the time in seconds for a pipette full of the juice to flow from the instrument in comparison with the time required for water at the same temperature.

Grapefruit equal to 10 to 25 per cent of the weight of oranges used is frequently mixed with the latter fruit in the preparation of juice for bitter marmalade.

Preparing the Sliced Fruit.—For the preparation of the usual English marmalade the whole fruit is used, and the juice and peel are not prepared separately, although the method described in the next paragraph is also used. The fruit is very finely shredded by a special machine designed for this purpose.

Three methods of preparing the peel are in use in marmalade factories in California. In one method a band of peeling about 1 in. wide is cut from the orange around its greatest circumference. This band is then cut crosswise into very thin slices about $\frac{1}{32}$ in. thick. The pieces possess a "shoe peg" appearance and give a very attractive marmalade.

In another method the whole fruit is sliced very thin and boiled until tender. It is then placed on screens and the yellow "rag" and pulp washed from the peels by a spray of water.

In one large factory the whole fruit is chopped finely by means of a mechanically driven mincemeat shopping bowl. No attempt is made in this case to prepare the juice and peel separately, in this respect resembling the English process. Marmalade prepared according to this method is cloudy and of jam-like rather than jelly-like consistency, but is of excellent flavor.

The writer prefers the second process, because of its convenience and of the attractive appearance of the finished marmalade.

Boiling and Packing.—In the usual process in California factories the juice and peel are combined after the latter has been boiled in water until tender. The proportion of peel to juice will depend upon the pectin content of the juice and upon the thickness of the peels. Where the slices are very thin and the juice is rich in pectin, about 5 to 7 per cent of the sliced peels may be added to the juice together with sugar equal in

weight to the juice. If the slices are relatively thick, a larger proportion by weight of peel can be added.

Where the whole chopped or sliced fruit is used without previous separation of the peel and juice, the fruit should be boiled until tender before sugar is added.

Addition of Sugar.—The amount of sugar that is required varies greatly with the composition of the juice and, as in jelly making, a relatively greater proportion of sugar can be added to juices rich in pectin and acid than to those deficient in one or both of these constituents. Equal weights of juice (*i.e.*, juice and fruit) and sugar is the normal proportion.

End Point.—The juice, peel, and sugar or sugar and sliced or chopped whole fruit are boiled to the jelling point, usually 220 to 221°F., or to the desired total solids content as determined by refractometer. The tests previously described for determining the finishing point of jellies can be used in the case of marmalades. A good marmalade should not be syrupy but should be of jelly-like consistency.

Cooling.—Marmalade should be allowed to cool partially and to stand a short time to permit absorption of sugar by the peel from the surrounding syrup before the marmalade is placed in the final containers, unless the whole fruit is used without previous separation of juice and peel. If packed boiling hot direct from the jelly kettles, the peels are apt to come to the surface instead of remaining in suspension.

Flavoring.—The boiling of marmalade removes a great deal of the orange oil from the peels, and the finished product, if made from commercial sweet varieties of oranges, is liable to be lacking in distinctive flavor. A small amount of orange oil or orange extract added to the marmalade and mixed with it thoroughly after the boiling has been completed will usually considerably improve the flavor.

Pasteurizing.—The marmalade should be sealed in glass or tin at about 150 to 180°F., as described elsewhere for jellies. Vacuum-sealed containers are best for the purpose, because they reduce the tendency of the product to oxidize. They should be pasteurized in water at 180°F., as described elsewhere for jellies.

Other Marmalades.—Excellent marmalade can be prepared by combining apple juice rich in pectin and acid with thinly sliced firm peaches, or figs similarly prepared or with other firm fruits. The juice and sliced fruit can be mixed with sugar and concentrated to the jelling point in the usual manner.

VACUUM CONCENTRATION OF JELLIES AND MARMALADES

Jellies and marmalades cooked in open kettles lose a large proportion of their flavor, aroma, and color by hydrolysis and evaporation, and the

color of red juices becomes brown if the boiling is prolonged, or if the jelly is concentrated too far.

The flavor and color of the fresh juice can be retained almost perfectly if the jelly is concentrated *in vacuo*. Some commercial manufacturers of jelly and orange marmalade are now using vacuum pans successfully in regular factory practice.

One difficulty that has been encountered has been the tendency of vacuum-cooked jellies to develop sugar crystals, but this difficulty can be overcome by boiling the sugar with a small amount of citric acid, to hydrolyze it partially before it is added to the fruit juice.

It is necessary to make frequent tests of the Balling degree, refractive index, or specific gravity of the mixture during boiling. Samples can be drawn from the pan by means of a sampling cock placed near the bottom of the pan.

For juices of red color, glass-lined or stainless steel equipment should be used in order to avoid injury to the color by contact with corrodible metals.

JELLY AND MARMALADE JUICES

Jelly manufacturers often preserve jelly juice by canning. Shredded oranges and juice are similarly preserved for shipment from Spain to England for the preparation of marmalade. The same method could be employed to advantage in the production, preservation, and sale of jelly juices and marmalade juice for the use of housewives in making jelly and marmalade in the home.

Semicommercial quantities of these products have been prepared in the Fruit Products Laboratory of the University of California and offered for sale to the local public with very encouraging results. Citrus fruit juices were canned; other juices were bottled, because cans did not withstand the action of the juice. Probably Type L cold-rolled-plate double-enameled cans would hold the juices satisfactorily.

For the use of housewives the juices must be partially concentrated before canning in order that there may be no difficulty in obtaining good jelly or marmalade. No sugar need be added to the juices at the time of canning.

USE OF DRIED FRUITS IN PREPARATION OF JELLIES AND MARMALADES

Large quantities of dried apple peels and cores from evaporating plants and of dried pomace from apple cider and vinegar factories have been used in the commercial manufacture of cheap jellies for bakers' use. The apple juice is prepared by soaking the dried material overnight, followed by boiling, pressing, and filtering as for the preparation of juice from the

resh fruit. It is then usually combined with berry juice or red grape uice; or artificial flavor and color are added.

Oranges and lemons can be dried and used for the production of narmalade and jelly, and loganberries are sometimes dried in prune evaporators and used for jelly making. The dehydration of these and other ruits does not materially impair their jellying quality, although there is some change in flavor and slight darkening of the color.

FROZEN-PACK FRUITS

Large amounts of frozen fruits, principally berries are used by jelly and jam makers. The fruit is frozen in 50-gal. barrels or 30-lb. cans without sugar, or with 3 or 4 lb. of fruit to 1 lb. of sugar. These fruits are used in much the same manner as the fresh (see Chap. XXXI).

CAUSES FOR FAILURE IN JELLY MAKING

Too Much Sugar.—The usual cause for failure is the addition to the juice of too much sugar in proportion to the pectin and acid of the juice. Firm jelly can be obtained by properly adjusting the proportion of sugar to the pectin and acid as previously determined by the alcohol test for pectin and by titration of the acidity.

Prolonged Boiling.—Too prolonged boiling results in the hydrolysis of the pectin and in the formation of a syrupy caramelized mass. The juice and sugar should be concentrated to the jellying point as rapidly as possible in order to avoid hydrolysis of the pectin.

Crystals.—At ordinary temperatures jelly may develop sugar crystals if the concentration of the finished product exceeds 70° Balling. During the normal boiling of jelly, some of the cane sugar is hydrolyzed to dextrose and levulose, which exhibit less tendency than cane sugar to crystallize.

Crystals of cream of tartar form in grape jelly, but this tendency can be reduced if before the addition of sugar the juice is concentrated by boiling and allowed to deposit its excess cream of tartar in storage. It may also be diluted with water and fortified with commercially prepared pectin or with other fruit juices to the point where crystallization does not occur when jelly is prepared.

RECIPES

It is believed that the producer will be able to prepare jelly and marmalade satisfactorily, provided the general principles and processes discussed in this chapter are followed. Many good recipes are to be found in Government and Experiment Station publications. Two or three tested recipes only will be given to serve as illustrations.

Berry Jelly.—Use sour berries, such as loganberries, currants, sour varieties of blackberries, etc. Crush. Heat to boiling in their own

juice for 3 min. Press through a heavy cloth. Strain through felt or filter through pulp until clear. Test pectin content of the juice by mixing 1 spoonful of the juice with an equal volume of 95 per cent grain alcohol. If the mixture forms a stiff jelly, add 1 lb. of sugar to each pint of juice; if a soft jelly-like mass forms, use about ¾ lb. of sugar per pint of juice; and if small separate lumps of a pectin precipitate form, use ½ lb. or less of sugar per pint of juice. Heat slowly, and stir until the sugar dissolves. Boil rapidly until a boiling point of 218 to 220°F. is reached. If jelly is made on a small scale, pour into glasses and seal; if on a large scale, cool to about 150°F., seal in glasses and pasteurize at 180°F. for 30 min.

Apple Jelly.—Use sour fruit. Crush or slice. Add water to cover. Boil 20 min. Press. Filter. Test for pectin and proceed as for berry jelly.

Marmalade from Sweet Oranges and Lemons.—Use equal weights of lemons and oranges. Slice about ⅛ in. thick. Add about three volumes of water. Boil 1 hr. Press. Strain to remove coarse pulp. Filter. Determine Balling degree, and make necessary temperature correction. If Balling is above or below 6° Balling, add water or concentrate by boiling, as the case requires, until this Balling is approximately attained. Cut and discard the ends from oranges. Slice the remainder of the orange into very thin pieces. Boil in water until tender. Drain off the juice, but do not press the fruit. Wash the cooked shreds on a screen under a vigorous jet of water to remove fine pulp. Combine the residual peel with the juice prepared from the oranges and lemons above, in the proportion of about 1 lb. of sliced peels to 10 pt. of juice.

If the juice exhibits a good pectin test, add an equal weight of sugar and concentrate to the jelling point as directed for berry jellies. Allow to stand for about 30 min. to permit equalization of the sugar in the peels. Pack into glass or tin containers at about 150 to 170°F., and seal. Pasteurize as directed for berry jellies.

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CHAPTER XVIII

FRUIT JAMS, BUTTERS, PRESERVES, AND CONFECTIONS

Fruit jams, butters, and preserves are very generally used throughout the civilized world. The people of the British Empire are probably the most important manufacturers and consumers of jams; France is noted for preserved and candied fruits of high quality; China produces preserved ginger root and candied fruits, which are well-known articles of world commerce, and India is famous for a fruit relish known as "mango chutney."

Housewives pride themselves upon their preserves and jams and probably a greater quantity of fruit is used for these purposes in the home than is used in the factory production of jams and preserves.

DEFINITIONS

The definitions given below conform to the usual conceptions of the products in question.

Jam.—Jam is prepared by boiling the whole fruit pulp with sugar (sucrose) to a moderately thick consistency without retaining the shape of the fruit. The United States Government pure food regulations require the use of not less than 45 lb. of fruit to each 55 lb. of sugar. In England a jam is usually considered to consist of fruit pulp cooked with sugar to a jelly consistency.

Fruit Butter.—This product is prepared by boiling the screened fruit pulp with or without the addition of sugar, fruit juices, and spices to a semisolid mass of homogeneous consistency. It differs from jam in being of higher concentration and finer consistency. It is usually heavily spiced and is frequently prepared without the addition of sugar.

Fruit Paste.—Fruit paste or fruit leather, etc., is prepared as described for fruit butter but is dried in the sun or by artificial heat to a solid consistency or to approximately the consistency of putty.

Fruit Preserves.—Preserves are made by cooking the prepared fruit in sugar (sucrose) syrup until the concentration of sugar reaches 55 to 70 per cent. The fruit should retain its form, should be crisp rather than soft, and should be permeated with the syrup without shriveling of the individual pieces. Government regulations require the use of not less than 45 lb. of fruit for each 55 lb. of sugar.

Candied Fruits.—Candied fruits are prepared by gradually concentrating fruits in syrup by repeated boilings until the fruit is heavily

impregnated with sugar, this process being followed by drying to overcome stickiness. *Glacé* fruit is prepared by coating candied fruit with a concentrated solution of sugar and confectioners' glucose syrup followed by careful drying to give a transparent glaze to the surface.

Fruit Confections.—This is a general term used to describe candies in which fruits are used. There are on the market a large number of products of this character which vary greatly in appearance, texture, flavor, and in the proportion of fruit used in their manufacture.

STORING FRUIT FOR JAM AND PRESERVES

In America berries, cherries, and other fruits are barreled with or without sugar and preserved in freezing storage until used for jams or preserves. In Great Britain fruits are packed in barrels and preserved with dilute sulfur dioxide solution, 1,000 to 3,000 of SO_2 p.p.m. The sulfur dioxide is boiled out of the fruit almost completely in making jam later.

JAMS

Jam may be made from practically all varieties of fruits and from some vegetables. In the United States and in the British Empire the small fruits and berries are most popular for the purpose.

Various combinations of different varieties of fruits can often be made to advantage, pineapple being one of the best for blending purposes because of its pronounced flavor and acidity.

Preparation of the Fruit.—Fruit for jam making should have reached full maturity in order to possess a rich flavor and be of the most desirable texture.

All berries must be carefully sorted and washed; strawberries must be stemmed; peaches, pears, apples, and other fruits with heavy skins must be peeled; while apricots, plums, and other thin-skinned fruits do not require peeling.

Firm fruits should be boiled in a small quantity of water before sugar is added in order to facilitate pulping. In factory practice it is possible to pulp boiled or steamed fruit in a tomato pulper without previous peeling. Stone fruits, such as plums and apricots, require a very heavy pulping screen because of the abrasive action of the pits. The paddles should operate at moderate speed, so that the pits will not be broken into fine fragments. For jams a coarse screen is used and for butters, a fine one.

Berries should not be softened by boiling before the addition of sugar but need only be crushed.

Addition of Sugar.—Pure fruit jam as defined by the pure food and drug regulations contains only fruit and cane sugar. Glucose may also be used under the present regulations.

The proportion of sugar to fruit varies with the variety of the fruit, its ripeness, and the effect desired, although the most common ratio of sugar to fruit is pound per pound. This is usually a suitable ratio for berries, currants, plums, apricots, pineapple, and other tart fruits. Sweet fruits of low acidity, such as ripe peaches, sweet prunes, and Vinifera varieties of grapes, normally require less than an equal weight of sugar, and the ratio may in some cases be as low as ¼ lb. of sugar per pound of fruit.

Boiling.—Boiling is desirable in order to cause intimate mixing of the fruit pulp and the sugar and partially to concentrate the product by evaporation of excess moisture.

Berries should be used in small lots and concentrated to the desired consistency as rapidly as possible. Other fruits are more resistant to the action of heat and may be boiled more slowly or in larger lots.

Steam-jacketed copper kettles are commonly used in commercial practice for the preparation of jams, small kettles being preferred.

End Point.—Most jams should be concentrated to a boiling point of 218 to 221°F., the end point varying with the fruit variety, proportion of sugar, and other factors. A jelly thermometer may be used with advantage to determine the end point of the boiling process. An Abbe refractometer is very useful in determining the finishing point, 55 to 70 per cent soluble solids depending on the product.

Use of Pectin.—The combining of fruit pulp with pectin or with apple juice is becoming a more general practice in the commercial manufacture of fruit jams, in order to obtain products of jelly-like consistency.

The use of fruit pectin is of doubtful value, particularly from the consumer's standpoint, because it permits of great dilution of the fruit pulp with water and sugar and masks the jam-like character of the product.

Vacuum Concentration.—Concentration of berry jams in an open kettle results in considerable loss of color and flavor. Experiments and recent commercial developments have demonstrated that a jam of fresh berry flavor and rich red color and in every respect superior to kettle-cooked jams can be made by concentrating the fruit pulp and sugar in a vacuum pan (see Vacuum Concentration of Jellies in Chap. XVII).

The capacity of the vacuum pan will be greatly increased if the fruit and sugar are heated to boiling in an open kettle before entering the vacuum pan. If desired, the vacuum pan may be used as an open kettle when the fruit and sugar are first added. This will be necessary for firm fruits that have not been previously subjected to boiling at atmospheric pressure.

Although greater skill is required in the operation of a vacuum pan than a jelly kettle, the output per man can be greatly increased where

vacuum concentration is substituted for the open-kettle method of preparing jams, jellies, and preserves, and superior products can be obtained.

Packaging.—Some of the jams produced in the British Empire are sold in cans ("tins"). In America the glass container is almost universally used for jams, jellies, and preserves. The processes of filling and sealing are done by automatic machinery, as described for jellies.

Pasteurizing.—If the product contains a very high concentration of sugar (70 per cent or above), it will not spoil in most climates. Most commercially prepared jams are not concentrated to this high density, however, and should be pasteurized at 180°F. for 30 min. as described for jellies, in order to prevent molding or fermentation.

Cooling before Placing in Containers.—If allowed to stand at a high temperature too long before packaging and pasteurizing, fruits of delicate color and flavor, such as strawberries, may be injured in quality. Such jams should be cooled as described for jellies.

Use of Glucose Syrup.—Low-priced jams for bakers' use and to some extent for retail sale are often made with glucose syrup and sugar. The glucose syrup imparts a heavy consistency and is lower in price than sugar.

FRUIT BUTTERS

The most important fruit butter produced in the United States is apple butter; peaches and plums are used to a limited extent for the same purpose. In continental Europe plums and prunes are used in very large quantities for the preparation of cheap butters and highly concentrated jams, and in Asia Minor the apricot is rather generally used for the purpose.

Preparation of the Fruit.—In the commercial manufacture of apple and pear butters the fruit is cooked until soft with a small amount of water and without previous peeling or coring. The softened fruit is then passed through a tomato pulper to remove skins and seeds and generally through a tomato pulp finisher to impart a smooth texture.

An apple crusher may be used to crush the fruit before boiling and pulping.

Peaches should be peeled before pulping, and other stone fruits, such as apricots, prunes, and plums, should be pitted, although it is possible to pulp these fruits if very heavy screens are used in the pulping machine. All fruits should be thoroughly cooked before pulping. An excellent pulper consists of a Sprague-Lowe type, tomato-catsup finisher equipped with revolving, stiff brushes and a heavy copper screen with about ⅛-in. openings.

One essential difference between a jam and a butter lies in the screening of the pulp used for the latter.

Preparation of Fruit Butter without Adding Sugar.—In the household- and orchard-scale preparation of apple butter, apple juice or apple syrup is often used to replace sugar, but the butter so produced is of a tart flavor. The cider may be added with or without previous concentration, the usual ratio being 1 gal. of fresh juice per gallon of pulp.

The cider and sauce are concentrated by rapid boiling to a thick consistency and spices are added near the finishing point.

Spices.—The usual spices are cinnamon, cloves, and allspice, used in proportion of about $\frac{1}{10}$ per cent each, that is, about $1\frac{1}{2}$ ounces per 100 pounds. A small amount of ginger and vanilla extract or nutmeg are also often used.

It has been found that a great deal of the essential oils of the spices will be lost if the spices are added before concentration is nearly completed. On account of its thick consistency it is necessary to stir the butter thoroughly after the addition of the spices.

End Point.—The finishing point is determined by consistency rather than by boiling point because the boiling point of the finished butter is dependent upon the ratio of pulp to juice and of pulp to sugar. The butter, when cold, should be thick enough to stand when a spoonful is placed on a plate and should not flow. It should, however, be thin enough to spread easily on bread.

Fruit Butters with Sugar.—In the preparation of fruit butters from pears and peaches, sugar is generally used instead of fruit juice. Brown sugar is often substituted for refined sugar because a finished product of dark color is usually desired.

The usual proportion is $\frac{1}{2}$ lb. of sugar per pound of pulp. The mixture is then concentrated to a heavy consistency and spiced as described above.

A process employed at the University of California for the manufacture of the pear butter above mentioned is as follows: The ripe fruit is carefully sorted and trimmed. It is crushed in an apple crusher and then boiled with a small amount of water until soft. The softened fruit is passed through a tomato pulper and subsequently through a tomato finisher. To each pound of the pulp is added $\frac{1}{2}$ lb. of sugar. The mixture is concentrated to 218°F., and approximately $\frac{1}{2}$ gal. of lemon juice is added per 10 gal. of original pulp. The mixture is then boiled to 221°F., and $\frac{1}{10}$ lb. each of ground cloves, cinnamon, and ginger and $\frac{1}{20}$ lb. of nutmeg are added per 10 gal. of original pulp. The boiling is continued for a short time, less than 3 min. The butter is canned and sealed hot, no further sterilization being required.

Plums and other sour fruits can be made into butters by the same formula with the exception that the lemon juice is omitted. Peach butter is improved by the addition of lemon juice as described above.

or pear butter or by mixing the pulp with that from plums or other sour fruit.

Preservation.—Fruit butters require no sterilization if packed boiling hot and sealed at once, or if concentrated to a boiling point of 221°F. or higher, but under other conditions they require pasteurization as described for jellies.

Butters that have been highly concentrated may be preserved satisfactorily by placing them in scalded jelly glasses, stoneware jars, etc., and sealing with paraffin.

CANNED SAUCES

Apples are peeled, cored, quartered, and cooked until soft, with 1 part of sugar to 5 of fruit and water to prevent scorching. The sauce is canned hot, sealed, and processed a short time at 212°F.

Other fruit sauces may be prepared in similar fashion.

PRESERVES

Fruit preserves of good quality should retain the form of the original fruit and should consist of the whole or cut fruit in a clear syrup of high sugar concentration. The fruit should not be caramelized by overcooking and should retain most of the color of the fresh fruit.

Preparation of the Fruit.—Fruit is prepared for preserving as for canning.

Open-kettle-one-period Process.—The usual process for the preparation of fruit preserves consists in boiling the fruit in steam-jacketed kettles with sugar or in syrup until a syrup of heavy density is obtained and the fruit is thoroughly impregnated with the syrup.

Firm fruits, such as peaches, pears, figs, etc., require a long period of boiling in order to impregnate them with the syrup, while berries should be boiled only a very short time in order that the fruit shall not be badly softened.

The end point of the boiling process is most conveniently determined by means of a thermometer, or by an Abbe refractometer, as in the preparation of jelly. The syrup should have a final concentration for most fruits of 60 to 65° Balling, or the boiling point of the finished product should be approximately 218 to 220°F.

The objection to the open-kettle-one-period process is that it may result in serious injury to the flavor and color of the finished product. Its advantage lies in its rapidity and low cost of operation.

The Slow Open-kettle Process.—In order to avoid undue injury to the color and flavor of the fruit, the slow process of preserving, may be employed in which the fruit is heated for a short time on successive days in syrups of progressively increasing sugar concentration.

It is customary to place the fruit first in a solution of 39 to 40 per cent sugar and boil long enough to render the fruit tender but not soft. The mixture is then set aside for 24 hr. More sugar is added to increase the sugar concentration about 10 per cent above that of the first syrup. The mixture is then boiled a short time, usually 3 or 4 min., and is set aside again for 24 hr. The process is repeated until the product is of the desired consistency. It is then placed in the final containers and sterilized.

Vacuum Cooking of Preserves.—The advantages enumerated for the vacuum cooking of jams apply equally well to the vacuum cooking of preserves.

Fruit that is to be cooked in vacuum should first be cooked sufficiently at atmospheric pressure to render it tender.

For firm fruits, concentration must be slow in order to permit penetration of the fruit by the syrup. Soft fruits may be concentrated rapidly.

The finishing point is determined by the Balling test or by refractometer readings of samples of the syrup withdrawn while boiling is in progress. There is danger of concentrating the syrup to such a point that crystallization of the cane sugar occurs, and the final concentration should not exceed 65° Balling.

Vacuum-cooked preserves are superior in flavor and color to preserves made in an open kettle.

Cooling of Preserves.—In order to retain the fresh flavor and color of the fruit most satisfactorily the preserved fruit should be cooled as soon as possible after the cooking process is completed.

Sterilizing.—If filled into the jars or cans boiling hot, preserves need not be sterilized in the container, but in commercial practice it is generally desirable to pasteurize as described for jellies.

Preserving Methods for Various Fruits.—The processes of preparing preserves from various fruits differ considerably in important details and it is therefore deemed advisable to give brief descriptions of the more common methods followed in preserving some of the more important fruits.

Strawberries.—Use firm ripe berries of good color. Sort carefully and stem. Place in a preserving kettle with an equal weight of sugar. Heat slowly to the boiling point with gentle stirring. Avoid crushing of the fruit. Boil 3 to 4 min. Chill to room temperature as quickly as possible on a cooling table or by circulating cold water in the jacket of the kettle. Allow to stand with occasional gentle stirring until the berries have thoroughly absorbed the syrup and have ceased to float. This may require several hours.

Pack into glass jars, and seal jars in a vacuum sealer. Pasteurize in water at 180°F. for 30 min. Cool to room temperature as rapidly as the glass will permit.

In the vacuum cooking of strawberries place the berries and sugar in a vacuum kettle equipped with a stirring device. A small amount of water should be added to prevent crushing of the berries by the stirrer. Heat to boiling in the open kettle for about 2 min. to soften the berries and thoroughly dissolve the sugar. Place the kettle under vacuum and concentrate to a 60° Balling. Release vacuum; withdraw berries; pack into jars; and pasteurize as directed above. Cool pasteurized jars at once. The principal danger in the vacuum cooking of berry preserves lies in the

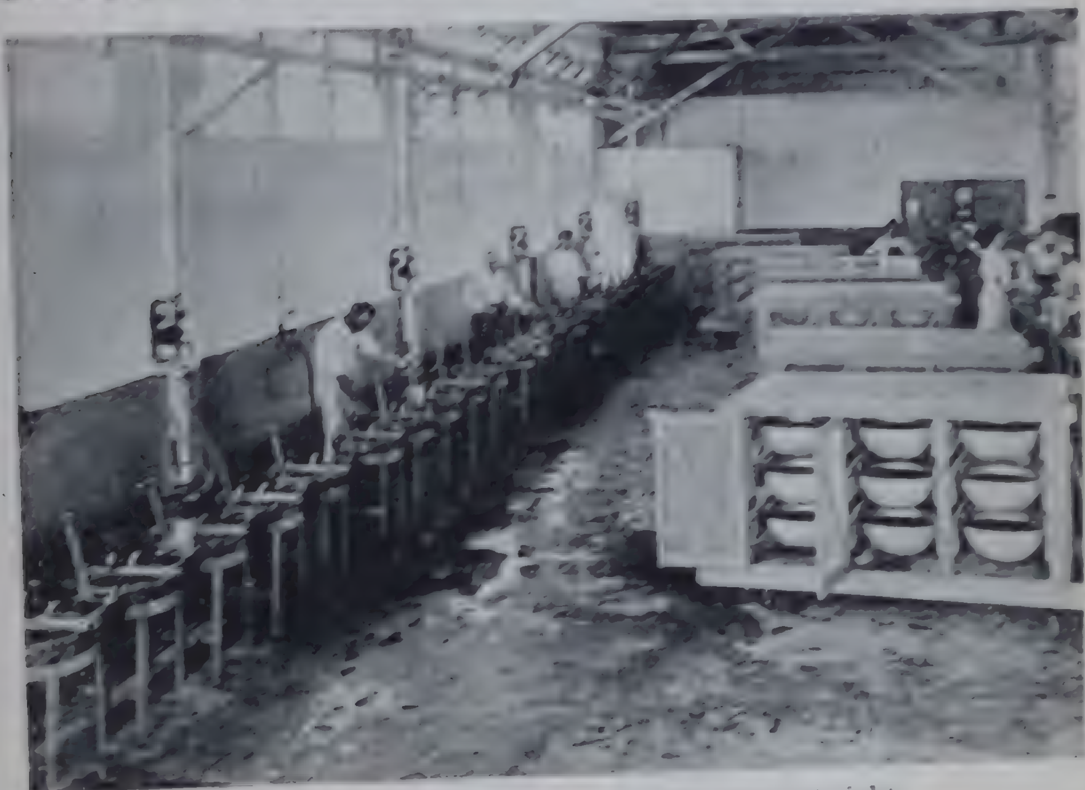

FIG. 64.—Preserving room. Cooling pans at right.

fact that, if concentrated too highly, cane sugar will crystallize in the finished product.

Other Berries.—Other berries may be preserved in the same manner as described for strawberries, although they are not so liable to soften and disintegrate as are the latter and will usually withstand more vigorous and longer boiling than will strawberries.

Fig Preserves.—A number of methods are in commercial use for preserving figs. In Texas the Magnolia variety of fig is used. The fruit is lye peeled in boiling dilute lye (usually about 1 per cent sodium hydroxide) and is rinsed under sprays of water. It is placed in a dilute syrup of approximately 30° Balling, slowly concentrated by boiling in open kettles to 60 to 65° Balling, packed hot in jars or cans and sealed at once. Sterilizing in the container is usually omitted.

In California the slow process is sometimes used. The figs, usually of the Kadota variety, are blanched in water near the boiling point until

tender. They are then boiled a short time in dilute syrup or are heated to 185°F. and then set aside for about 12 hr. On succeeding days the syrup concentration is progressively increased and the heatings repeated until the desired consistency is obtained.

In another process the blanched fruit is placed in syrup at 180 to 190°F., and this temperature is maintained for about 2 hours, during which period the sugar concentration is increased by the addition of sugar which is dissolved by stirring. The fruit is then set aside in the syrup overnight and packed. The finished product is of very attractive appearance and flavor.

Single-period boiling of the fruit in open kettles is more commonly used in California but results in considerable breaking of the fruit and rather heavy loss during sorting and packing. Approximately equal parts by weight of blanched figs, water, and sugar are cooked to 218 to 220°F. The boiled fruit should be allowed to stand overnight to absorb the syrup before packing. The broken fruit must be used for jam, which is sold at a lower price than the preserves.

During the harvesting season a large proportion of the figs are canned in water and later used for preserving.

Peaches and Pears.—These fruits are peeled and cored or pitted as for canning and, in addition, usually sliced. Peaches may be lye peeled whole, cut lengthwise, but not pitted, and cooked to a preserve as follows:

The prepared fruit is placed in a syrup of approximately 30 per cent sugar and is boiled slowly to the desired concentration. This will be for peaches about 55 to 60° Balling and for pears about 50° Balling (corrected for temperature). If placed in too concentrated a solution, the fruit will shrivel and become tough. The use of a dilute syrup for the preliminary stages of the process softens the fruit and permits penetration of the fruit by the syrup.

A modification of the above process consists in boiling the fruit in water until tender, followed by the addition of sugar and a small amount of water to give a heavy syrup in which the fruit is cooked a short time.

Cherry Preserves.—Sour cherries are pitted mechanically and cooked to a preserve consistency with water and sugar equal in weight to the fresh fruit. Sweet cherries, such as the Royal Anne and Black Tartarian, are seldom used in this manner. Royal Anne cherries are more often used for preparation of Maraschino cherries (see next section).

Maraschino Cherries.—With the advent of canned fruit salad and canned fruit cocktail large quantities of cherries, usually Royal Anne and other white varieties, came into use for barreling and subsequent preparation of Maraschino cherries. Considerable quantities of barreled cherries also are used in preparing Maraschino cherries in syrup for use in mixed

inks, ice cream, etc. Barreled cherries are used also in preparing ndied and *glacé* cherries for confectioners' and bakers' use.

Barreling is a simple procedure; although if improperly done, *i.e.*, too little preservative (sulfur dioxide) is used, it may result in complete ss of the fruit by fermentation or in softening if too much sulfur dioxide used.

The orchard run of fruit, usually Royal Anne or other white variety, gathered before it is fully mature. Royal Annes should have attained ll size but should not have developed much pink color or no color at all,

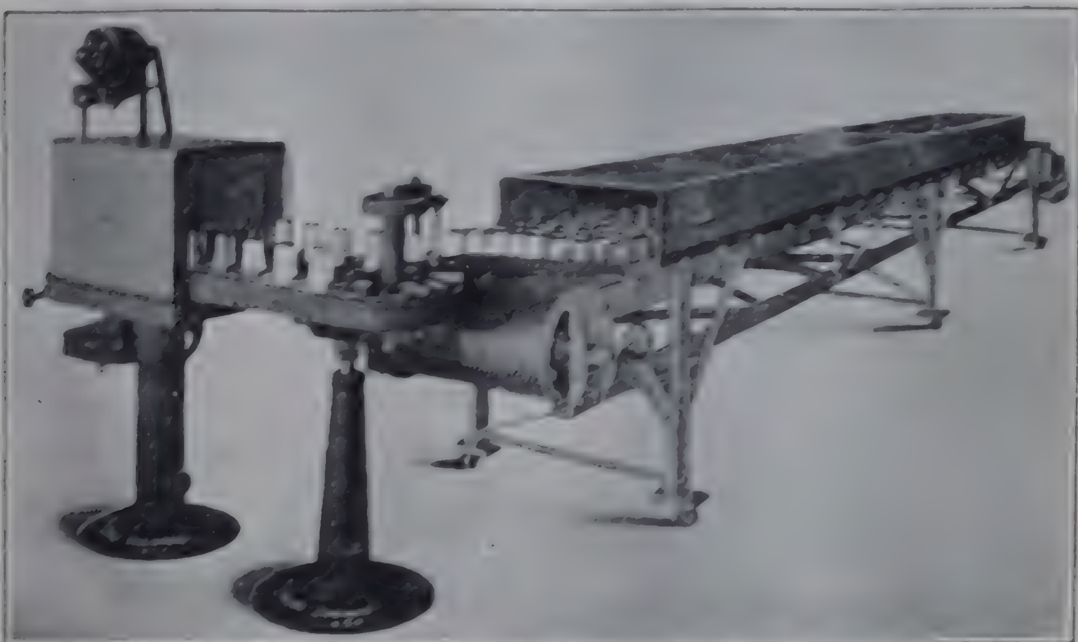

FIG. 65.—Washing and drying equipment for jam and jelly glasses. (*Courtesy The Karl Kiefer Co.*)

i.e., they should be white in color or colored with only a faint "blush" of pink. The stems are usually not removed at this time. Red varieties of cherries may be used if picked slightly immature.

The fruit is packed in paraffin-lined spruce barrels after removing one head from the barrel. The head is replaced, the hoops driven in place, and the barrel is filled with the preservative brine. The usual brine employed in California is made up of about 0.75 to 1.0 per cent of sulfur dioxide and about 0.4 to 0.6 per cent of unslacked lime, *i.e.*, a little more than half as much lime is used as sulfur dioxide. If too little lime is used the resulting low pH value will cause splitting of the cherries and cracking of the skin. If too much lime is used, the sulfur dioxide will have no preservative effect and spoilage by yeast will ensue. In Oregon approximately 1.5 per cent sulfur dioxide and about 0.90 per cent of lime are used.

In preparing the brine the water is measured into a tall wooden tank. The lime is weighed and is made into a thick milk of lime with a few gallons of water. This milk of lime is then added to the tank of water and maintained in suspension by a mechanically operated wooden stirrer.

At the same time a cylinder of liquefied sulfur dioxide is placed on a portable scales and connected to a tube which enters the bottom of the tank. Iron should be avoided. The desired amount of sulfur dioxide by weight is bubbled into the lime suspension in the tank with constant stirring. The lime goes into solution because of formation of calcium bisulfite, $Ca(HSO_3)_2$, and when the reaction is complete, a nearly clear solution results.

The sulfur dioxide content of this solution should be checked by titration with standard N/10 iodine solution, using starch solution as an indicator. A 10-cc. sample plus 50 cc. of water plus about 5 cc. of 1:3 sulfuric acid is satisfactory for titration. One cubic centimeter of N/10 iodine equals 0.0032 gram of sulfur dioxide. The titration is made directly without need of distillation.

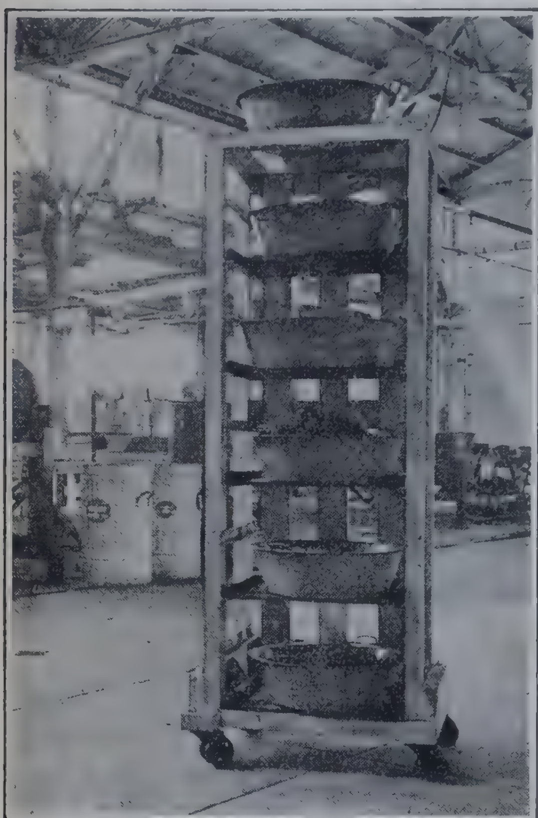

FIG. 66.—Convenient rack for transferring berries or other fruit in a preserving factory.

The brine is added to the barreled cherries, and the barrels are bunged tightly. It is often desirable to add more brine after 24 hr. to fill the space formed because of absorption of the brine by the fruit and wood of the barrel. The barrels should be rolled once a day for several days to ensure dissolving of all the lime, because if undissolved lime is present, it may settle to the bottom of the barrel where it may cause the liquid to be alkaline or neutral, with subsequent damage to the fruit.

After about 4 weeks' storage the cherries are usually ready for use, although the barreler observes the degree of curing by noting the color and texture of the fruit. The sulfur dioxide bleaches it to a translucent, white or cream yellow color. The calcium hardens the tissues, probably by combining with pectic substances. Some barrelers also add alum to the brine but this may so increase the hydrogen-ion concentration that cracking and softening result.

If to be used in canned fruit salad or canned fruit cocktail, the cherries at the cannery are stemmed and pitted by hand, either by a small pitting spoon or by special, power-operated, small plunger-type pitter. The pitted fruit is soaked 24 to 48 hr. in barrels in running water to remove most of the sulfur dioxide. It is then boiled in several changes of water in steam-jacketed copper kettles until tender and until the sulfur dioxide

content is reduced to below 20 p.p.m. If too much sulfur dioxide is left in the cherries, the canned product will attack the tin plate, causing hydrogen swelling, or if very much sulfur dioxide is present, formation of hydrogen sulfide and black ferrous sulfide will occur.

The cherries are then boiled a few minutes in dilute erythrosin dye solution (0.02 to 0.05 per cent usually). This dye is precipitated by the acid of the fruit and therefore penetrates only a short distance into the flesh. The fruit is allowed to stand in the dye in open barrels for 24 hr., when it may be boiled a second time. It is then rinsed in water and added to the other fruits used in canned fruits for salad or in canned fruit cocktail. For the latter product the cherries are sliced or quartered. This method of dyeing the fruit greatly reduces its tendency to "bleed" and stain the other fruits with which it is canned in salad and cocktail. Some authors recommend dyeing the cherries in a dilute sodium bicarbonate solution of erythrosin, as the bicarbonate renders the fruit alkaline and hence the dye penetrates deeply and quickly. The fruit is then acidified by storage for 24 hr. in dilute (0.5 per cent) citric acid solution. This procedure gives an evenly colored cherry, but the dye bleeds badly after canning and stains the surrounding fruit. Therefore, the writer prefers the first method described above.

In preparing cherries for use in cocktails a somewhat different procedure is employed. The cherries are pitted, "soaked out" with cold water, and boiled in several changes of water until tender and practically free of sulfur dioxide. In this laboratory the following cooking procedure has proved satisfactory: To a cane sugar syrup of 40° Balling is added 0.20 per cent sodium benzoate, 0.5 per cent citric acid, and 0.02 per cent ponceau 3R dye. The fruit, previously pitted and freed of sulfur dioxide as described above, is then added and the mixture boiled 2 to 3 min. The syrup and fruit are set aside in dishpans for 24 hr. to absorb the syrup. The syrup is removed and sugar is then added to it to increase the Balling to 40°. It is heated to boiling with the fruit and again set aside for 24 hr. The syrup is again brought to 40° Balling by addition of sugar; artificial cherry flavor is added to suit; the fruit and syrup are again brought to boiling, packed hot, and sealed in small glass jars. The flavoring may be purchased from any reputable bakers' and confectioners' supply company, or may be prepared by dissolving about 5 per cent of pure bitter almond oil in pure ethyl alcohol (free of wood alcohol) and adding small amounts of neroli oil and pure vanilla extract made from vanilla beans. This is a very powerful flavoring agent. Avoid overflavoring of the syrup.

The sodium benzoate is for the purpose of preserving the cherries after the jar has been opened. Its presence must be declared on the label.

For candying, Atkinson recommends dyeing the cherries with dilute erythrosin in preference to ponceau 3R. Some preservers prefer a mixture

of ponceau 3R and amaranth, about 0.01 per cent of each. These two dyes are soluble in the presence of acid, whereas erythrosin is precipitated at even very slight acidity. Ponceau 3R is brick red in color, amaranth purplish red, and erythrosin is deep pink in color.

See last part of this chapter for the candying of cherries and other fruits.

Spiced Preserves (Sweet Pickles).—Spiced preserves are prepared principally on a household scale, but it is believed that their manufacture on a commercial scale should provide a considerable outlet for fruits suitable for preserving purposes.

Peaches, pears (particularly small varieties such as the Seckel), figs, quinces, and other firm fruits are those most commonly used for sweet pickles.

The fruit is prepared as described elsewhere for sweet preserves, boiled in water until tender, and then placed in a spiced syrup. The formula given below is typical of the syrups used for the purpose.

Sugar	14.0 lb.
Vinegar (cider vinegar of 4 per cent acetic acid)	3.0 pt.
Water	7.0 pt.
Ginger root, broken	½ oz.
Whole cloves	½ oz.
Stick cinnamon	½ oz.

The fruit is heated to boiling in this syrup and allowed to stand overnight. The syrup is then increased to 60° Balling by the addition of sugar. The fruit and syrup are heated for 3 or 4 min. and are packed boiling hot into jars or cans. Normally no further processing is necessary, although if the syrup and fruit cool to below 180°F. before packing in the final containers, the product should be pasteurized at 180°F. for 30 min. or processed at 212°F. for 10 min. to insure against spoilage. If the spices are tied in a cheesecloth bag, they may be removed from the syrup after preserving is completed (see also Chap. XI for canning or spiced fruits).

CANDIED FRUITS

The manufacture of candied and *glacé* fruits has in the past been a highly specialized industry in which success has depended to a very great extent upon the skill and experience of the individual workmen. A very large proportion of the work has been done by hand labor and with small individual lots of fruit. Undoubtedly, the processes for the candying of fruits lend themselves to factory methods, and existing factory equipment could be employed to greatly reduce the cost of manufacture and the price to the consumer.

General Principles.—The candying process consists essentially of slowly impregnating the fruit with syrup until the sugar concentration in

the fruit is high enough to prevent spoiling. The process must be so conducted that the fruit does not soften and become jam or become tough and shriveled. Repeated boiling and storage in syrups of progressively increasing sugar concentration will accomplish the desired results.

Following impregnation, the fruit is washed and dried. It may be packed and sold in this form, or it may be coated with a thin glaze of sugar and glucose syrup—*glacéd.* This is done by dipping the dried candied fruit in a syrup and again drying the surface.

Preparing Fruit.—Frequently the fresh fruit is stored in a dilute solution of sulfurous acid, or sulfur dioxide and lime solution, in order to bleach the color, harden the tissues, and to preserve it until needed, as described for Maraschino cherries.

Whole Fruits.—Fruit preserved in sulfurous acid must be thoroughly leached repeatedly in hot water to remove all taste of sulfur dioxide before the candying process is begun. Cherries are stemmed and carefully pitted before leaching. Apricots should be pitted without cutting the fruit in half. Small pears, plums, prunes, and other whole fruits are often pricked with copper wires.

Fresh fruits can be used for candying purposes without the intermediate step of storage in sulfurous acid. Figs, peaches, pears, and pineapple are particularly well suited for use fresh.

The jujube, or Chinese date, now produced in commercial quantities in the United States, is excellent for the preparation of candied fruit. The skin of the fruit must be punctured very thoroughly by means of metal needles, or slit.

Berries are very difficult to candy because of their tendency to soften.

Other fruits should be boiled in water until tender, after preparation as described above.

Use of Canned Fruits.—All firm varieties of canned fruits may be used very satisfactorily, pineapple, peaches, figs, and pears being particularly desirable for the purpose.

Firm Fruit Necessary.—Frequently fruit which is at the best stage of maturity for table use is too soft for the preparation of candied fruits. Firm ripe fruit or even that which is slightly immature is better than thoroughly ripe fruit.

Syrup Treatment.—As at present practiced, the impregnation of the fruit with sugar is a process that requires a long period of time and frequent manipulation of the fruit in small containers.

Commercial practice varies greatly in regard to the application of the syrup; hence the process described below is general in nature, although found to give good results in experiments made upon a semicommercial scale.

and enough water to give the desired Balling d
tration of 30° Balling will be obtained by diss
of the mixed glucose and sugar in 2 pt. of wate

Unless glucose or invert syrup is used, th
completely and become hard and granular.
drying and also improves the appearance of th
ing it to be more translucent than would othe
syrup is better for the purpose because candied
become tough and hard as it does when made

The fruit, prepared by previous treatment i
to render it tender, or by boiling of the prepa
the syrup. Canned fruits are placed in this
The fruit and sugar are boiled for a short time,
is then set aside for 24 to 48 hr. to permit e
the fruit and syrup. Large dishpans are ordin
Small steam-jacketed tilting jelly kettles are us
syrup.

If the fruit tends to float, it may be subme
of a floating wooden rack or wire screen.

After 24 hours' or longer storage the syru
and is made up to approximately 40° Balling by
and glucose, by weight approximately 1 part
sugar. For the Maraschino type of candied ch
colored by the addition of a small amount of p
such as erythrosin or ponceau 3R.

The fruit is brought to the boiling point in
aside for 24 to 48 hr. The shorter time is p
fermentation and molding. The syrup is then
the manner described above, and the fruit is
aside for another 24-hr. interval. The process
days, with an increase of 10° Balling each day
approximately 72° Balling. Better results are
syrup concentration 5° Balling, rather than 10°

This concentration is maintained until the
oughly equalized in sugar concentration. The

ready for drying.

om the syrup, and the surface is washed with a fruit is dipped momentarily in boiling water. to dry. Drying may be accomplished at room e more rapidly and with more uniform results a temperature of 120 to 140°F. If dried at too rup may dry in the form of flakes and separate

ontinued until the fruit is no longer too sticky marks are to be avoided, the fruit should be cial forks.

uit is usually coated with a thin, transparent dries to a more or less firm texture.

ave used a syrup made of about 3 parts of cane 2 of water cooked to a boiling point of about 236 ve the boiling point of water). This is cooled drained, dried candied fruit is dipped in it by ping "spoon." It is drained on screens and is t 120°F. On cooling, the coating should be ss.

hat drained candied fruit may be coated fairly in a 1½ per cent pectin solution and drying at his coating is not glossy, nevertheless is fairly ty. This process is covered by public service ithout payment of royalty.

of Citrus Peels.—Large quantities of candied peel are used in bakery products and confec- ommerce exists in the brining of citron peel in ance, and Palestine, with export to the United other countries. The brined peel is converted ories in importing countries.

brining is described by American Consul A. S. lows: The citron, which is a citrus tree fruit ught to the seashore, where each fruit is split in halved fruit is placed in large casks ("pipes"). d on their sides, and filled with sea water. The

with sea water, bunged, and rolled to dissolve the salt. They are then ready for export.

McCulloch states that, owing to the cooler temperature, fermentation of the peel in brine lasts about 40 days in Corsica. She states that a certain yeast and a bacterium seem to be essential to proper curing of the peel.

In experiments with Californian citron peel, D. Glickson and the writer found that storage in fresh sea water reinforced with 15 per cent of salt gave better results than the Corsican and Sicilian method; as excessive softening occurred in these latter brines. Storage in 15 per cent pure salt brine (60° salometer) containing 2,000 p.p.m. of sulfur dioxide gave a product of light color and of excellent candying quality, although not of so rich a flavor as that stored in brine containing no sulfur dioxide. Softening occurred in brines of initial salt content of less than 15 per cent salt (60° salometer). During storage such a brine decreases to about 8 per cent salt. It was found necessary to seal storage containers, after fermentation ceased, in order to prevent mold growth. Yeasts were the principal organisms found during fermentation. The addition of 1 per cent of calcium chloride to plain salt brine gave a very firm peel.

Candying consists in removing the central juice tissue, boiling the fruit in several changes of water to remove salt and to make the peel tender, followed by treatment with syrup. This latter consists in candying by the slow process in syrups of progressively increasing sugar content as described previously for other fruits. Equal weights of invert syrup and cane sugar, or of glucose syrup and cane sugar, are used in preparing the syrups. The initial syrup is about 30° Balling, and the final is 75° Balling. The process requires about 10 days to attain 75° Balling. The fruit is stored in this final syrup for several weeks, is drained, wiped free of syrup with a wet cloth, and dipped in saturated hot sugar syrup. On drying, the fruit then acquires a sugar coating.

Orange, grapefruit, and lemon peels may be handled in similar fashion except that fermentation should be avoided. A brine of 15 per cent salt (60° salometer) and 2,000 p.p.m. of sulfur dioxide is recommended. Candying is as described for citron. The juicy pulp is removed from orange and lemon peel, but not from citron, before brining.

USE OF FRUIT FOR CHOCOLATE-COATED CANDIES

Fruits lend themselves well to coating with chocolate and are used in a variety of forms for this purpose.

Chocolate-coated Frozen Fruit.—Fresh fruit has been used successfully for chocolate dipping, although only that which is very sweet meets with favor from the consuming public. The fruit may be used whole or in the form of ground pulp. In either case it is frozen and is then dipped in melted confectioners' chocolate.

The chocolate congeals at once, and the dipped product must be held in a refrigerator until served.

It is possible to mix gelatin, agar-agar, pectin, or other gelling material with the pulp and sugar and so obtain a product that will solidify at room temperature and can be coated.

Chocolate-coated Candied Fruits.—Fruit may be candied as previously described and may then be successfully dipped in chocolate. The chocolate should be melted at not above 100°F. and should be used at about 85°F. in order to prevent streaking and whitening of the coating.

Use of Jellied Fruits for Chocolate Centers.—Chocolate coated centers of jelly-like consistency can be readily prepared by mixing fruit pectin with fruit pulp and sugar in the proper proportions. In commercial-size experiments at the University of California various fruits were converted into pulp by boiling and pulping in a tomato pulper to remove seeds and skins. To the pulp was added enough commercial pectin, as determined by trial, to give, on concentration to 222 to 224°F. with invert syrup or glucose and sugar equal to the weight of fruit, a product which on cooling solidified to stiff jelly. The jelly was allowed to harden in a layer about ½ in. thick and was cut into square pieces of convenient size for coating with chocolate, or the hot jelly was cast in starch molds and allowed to solidify.

Some of the pieces were coated by hand dipping and the remainder by means of an enrobing machine. The finished product kept well and proved popular with the candy-consuming public.

Bursting of the chocolate coatings occurred when the fruit was concentrated to 218 to 219°F., but little difficulty from bursting was encountered in centers previously concentrated to 222°F. or above. It is desirable to allow the cut pieces of jellied fruit to dry in the air for 2 or 3 days before coating with chocolate.

The jelly was also cast in confectioner's starch molds in the same manner as ordinary gumdrops. On standing 24 hr., the cast pieces were separated from the starch and coated with chocolate or with coarse sugar. In the latter case the pieces were moistened with a wet towel and rolled in coarse confectioner's sugar.

A typical formula used in our semicommercial tests is as follows:

	Pounds
Fruit pulp	50
Cane sugar	45
Invert syrup	45
Powdered pectin	1.5
Citric acid	0.5

Dissolve the pectin by mixing it with 10 lb. of the cane sugar and adding it to about 2 gal. of water at 130 to 140°F., stirring, and finally boiling a short time. Dissolve the acid in 1 pt. of hot water.

Add the pectin solution to the fruit in a jelly kettle. Mix well. Add the remainder of the sugar and the invert syrup. Boil to 222°F., *i.e.*, to a boiling point 10°F. above the boiling point of water for the locality. Add the citric acid solution at this point. Stir well. Cook to 223°F. and cast in starch or pour on an oiled slat to harden.

Other fruit candies are described by Cruess and O'Neill. The writer believes that there should be an important market for low-priced fruit candies because of their healthfulness, as well as their pleasing flavor.

Use of Dried Fruits in Candies.—Dried fruits require no further concentration in most instances when used in candy. Raisins are in general use by confectioners for the preparation of chocolate-coated clusters, in which peanuts may be mixed with the raisins.

Raisins are also ground to a paste and mixed with chopped nuts and formed into pieces of convenient size, which are then dipped in chocolate.

Dates and prunes are frequently pitted and stuffed with fondant or nut meats. These fruits also yield a satisfactory candy when ground to a paste, mixed with fondant or chopped nuts and dipped in chocolate. Many dried fruits can be chopped and mixed with nougat candy successfully.

Flavoring of Cream Centers with Fruit.—Cream centers for chocolates are generally flavored artificially and colored with permissible coal tar colors. It has been found that highly concentrated fruit pulp or fruit syrup can be employed for this purpose to produce centers for chocolate coating that are superior in flavor and general quality to the imitation products made without the use of fruit.

Manufacture of Candy Bases from Fruits.—Fruit products factories could, with profit, investigate the manufacture of fruit syrups, fruit jams, jellified fruit products, and dried fruit preparations for the use of confectioners, and probably such products would provide a large outlet for surplus fruits as well as improve the quality of candies.

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CHAPTER XIX

TOMATO PRODUCTS

The most important relish used on the American table is tomato catsup; and southern European peoples, particularly the Italians, use a large quantity of tomato paste, a highly concentrated tomato product, of which there is a large importation into the United States from Italy. Canned tomato puree is very generally used in restaurants and hotels for flavoring and for soups. Canned tomato soup is one of the best known soup stocks used in the American home. Hot sauce and chili sauce are much in favor, and in recent years canned tomato juice has become very popular.

DEFINITIONS

A joint committee representing the Association of American Dairy, Food and Drug Officials, the Association of Official Agricultural Chemists, and the U. S. Department of Agriculture has promulgated specifications for most tomato products. These standards are followed by pure food and drug officials in the enforcement of the pure food and drug regulations and often form the basis for contracts between manufacturers. The definitions adopted are as follows:

a. **Final Definitions and Standards for Strained Tomatoes and Tomato Paste.**—1. *Strained tomatoes* is the product obtained by straining sound ripe tomatoes, raw or cooked, through a screen that removes skins and seeds.

2. *Tomato paste* is strained tomatoes concentrated by evaporation, with or without the addition of salt, with or without the addition of basil leaf, with or without the addition of pure sodium carbonate or of sodium bicarbonate to neutralize a portion of the acidity, and contains not less than twenty-two per cent (22 per cent) of tomato solids determined by drying *in vacuo* at 70°C.

3. *Concentrated tomato paste* is strained tomatoes concentrated by evaporation, with or without the addition of salt, with or without the addition of basil leaf, with or without the addition of pure sodium carbonate, or of sodium bicarbonate to neutralize a portion of the acidity, and contains not less than thirty-three per cent (33 per cent) of tomato solids determined by drying *in vacuo* at 70°C.

4. *Strained tomatoes from trimming stock* is the product obtained by straining sound peelings, trimmings and pieces from ripe tomatoes through a screen that removes skins and seeds.

5. *Tomato paste from trimming stock* is strained tomatoes from trimming stock concentrated by evaporation, and otherwise the same as definition (2) above.

6. *Concentrated tomato paste from trimmings* is made from strained tomatoes from trimming stock concentrated and is otherwise the same as definition (3).

b. **Tentative Definitions and Standards for Tomato Pulp, Puree, Catsup and Chili Sauce.**—In the text which follows, the words "strained tomatoes" wherever used refer to strained tomatoes as previously defined:

1. *Medium tomato purée* is the product obtained by the evaporation of strained tomatoes, with or without the addition of salt and contains not less than eight and thirty-seven hundredths per cent (8.37 per cent) of tomato solids determined by drying at 70°C. *in vacuo*.

2. *Heavy tomato purée* is the product obtained by the evaporation of strained tomatoes, with or without the addition of salt and contains not less than twelve per cent (12 per cent) of tomato solids determined by drying *in vacuo* at 70°C.

3. *Ketchup, catsup, catchup* is the clean, sound product made from properly prepared strained tomatoes with spices, salt, sugar and vinegar, with or without onions and garlic, and contains not less than twelve per cent (12 per cent) of tomato solids.

4. *Chili Sauce* is the clean, sound, cooked product made from chopped, peeled, ripe tomatoes, chopped peppers, salt, sugar, spices and vinegar, with or without onions and garlic, and contains not less than . . . per cent of tomato solids. (Per cent of tomato solids not defined.)

The committee also established tentative standards for the various grades of purée from trimming stock, which correspond in per cent total solids to the percentages given above for purée from strained tomatoes.

TOMATO COLOR

Tomato products should have a deep red color, a quality which varies with the variety, the locality, maturity of the fruit, and process of manufacture.

Nature of Tomato Color.—Tomato color was first separated in pure form in 1876 by Millardet, who named it "solanorubin." It was again isolated by Schunck in 1903, who named it lycopene, a name generally applied to it today. Montanari proved that it is a hydrocarbon and Willstätter and Escher have proved that lycopene is an isomer of carotene (also formerly spelled carotin and found in tomatoes). Lycopene can be extracted from tomato pulp by ether or carbon bisulfide, and the crystals obtained by evaporating *in vacuo* an ether or carbon bisulfide solution of the pigment are dark to light carmine-red in color and of waxy consistency. The crystals when pure melt at 168°C. and possess the empirical formula $C_{40}H_{56}$. Lycopene rapidly oxidizes in contact with air and fades in color. Preserved in hydrogen, nitrogen, or carbon dioxide, it retains its color indefinitely.

Duggar states that in the absence of lycopene, the flesh of the tomato is yellow, owing to carotene and possibly xanthophyll, which are masked in the red fruit.

Color Changes during Ripening.—According to Hanson the deep green of the chlorophyll first fades to a greenish-white during ripening, which is followed by the development of a yellow or light-orange color. Under the microscope yellowish granules and orange crystals can be found in the parenchyma cells at this stage of the ripening process.

As the red color becomes apparent, dark or light, carmen-red needle-like or prismatic crystals of lycopene appear. These become grouped in bundles as the color becomes more intense and the yellow pigment decreases in amount.

Effect of Manufacturing Processes on Color.—The quality of tomato products depends to a large degree upon the color, and retention of the natural red color is one of the most important problems in the manufacture of tomato products. MacGillivray has given much attention to this subject.

Chlorophyll, the green pigment of unripe tomatoes, turns brown during cooking, thus greatly reducing the intensity of the natural red color, and if green fruit is used in excessive amounts, the color of the product will be brown or brownish red. Careful sorting will eliminate green fruit.

2 Tomato products should not be permitted to come in contact with iron because it causes lycopene to turn brown; and iron salts in catsup and other spiced tomato products combine with tannin from the spices to form iron tannate, a black compound, which may darken the color of the entire contents of the bottle or may form a dark deposit near the surface of the bottled product.

3 Copper salts also are injurious to tomato color; hence the desirability of using glass-lined equipment.

Prolonged heating causes lycopene to become brown, and the cooking and concentrating processes should be accomplished as quickly as possible if a product of bright-red color is desired. High temperatures are also harmful to the color, according to MacGillivray. For this reason concentration *in vacuo* usually yields a product of better color than concentration in an open kettle.

Cooling of the sterilized product should be prompt and thorough. "Stack burning" of insufficiently cooled canned tomatoes has been a frequent cause of poor color.

Munsell Color System.—The color of tomato products is now usually measured quantitatively by apparatus and according to procedure originally devised by A. H. Munsell. In brief, the method consists in comparing the color of the product with that of a whirling disk made up of cardboard segments of various colors, the segments being interchangeable and adjustable in respect to area exposed; or the eyepiece of the instrument may be revolved and the color disk then is stationary. The method

may be applied also to measuring the color of many opaque products, such as cotton fiber, hay, tobacco, butter, etc.

According to this system, color is understood to have three principal attributes, *viz.:* (1) chroma ("strength"), (2) hue ("tint" as red, pink, etc.), and (3) value (brilliance). The Munsell method is well described by Nickerson (see also Cleland).

The spectrum is divided into 10 hues ranging from R (red) through YR (yellowish red) Y (yellow), etc., to RP (reddish purple). Each hue is also divided into 10 divisions with numerical values of 1 to 10; thus 5R is midway in the R section of the spectrum.

In expressing results in this system, hue is represented as above by some such designation as 5R; value is expressed by the number above the line in the fraction and chroma by the number below the line; thus, 5R $3/2$ means that the hue is that of the middle of the red section of the spectrum, the "value" is 3, and "chroma" is 2 on their respective scales. In expressing the color of tomato products, the hue YR also is used with the hue R, supplemented by Neutral disks (so called). N1 is nearly black and N4 is gray; these being the "neutral" disks used with the R and YR disks to match the color of tomato products. Thus, the minimum color for Fancy and Standard tomato products is 5R 2.6/13 glossy finish, 2.5YR $5/12$, N1/ and N4/ (for further details of this system see Nickerson or Cleland).

The equipment used in canneries usually consists of a metal disk to which may be attached paper disks of the colors such as R, YR, N1/, etc., to be used for any given product. The area of each paper disk to be exposed can be varied at will. The metal disk is attached to a small variable-speed electric motor. The sample is placed in a dish beside the rapidly whirling color disks. The exposed areas of the different disks are varied until a color match is obtained. The area of each color exposed is then measured in per cent of total area of the disk.

TOMATO PURÉE

Certain tomato products are made from tomato pulp which represents the unflavored, finely divided flesh and juice separated from skins and seeds. It is usually concentrated to a greater or less degree before use in other products or for canning.

Tomato Varieties for Purée.—Tomatoes for purée, catsup, sauce, and other tomato products should be of smooth skin, should be free from wrinkles and folds, and should have a shallow stem cavity so that molds and other organisms may not accumulate in such cavities. They should be of deep red color, firm flesh, and small seed cavity and should ripen evenly. Size is not so important as in canning because the tomatoes are not peeled (except for chili sauce). In California the San Jose canner,

Santa Clara canner, Alameda Trophy, Norton, and Stone are commonly used for tomato products.

Picking, Transporting, and Storing.—Even greater care must be observed in picking, transporting, and storing tomatoes for purée, etc., than for canning, because the former are not peeled. Boxes should be washed frequently and not allowed to become moldy. The fields should be picked daily during the height of the ripening season to avoid gathering of unripe and overripe tomatoes. They should be transported to the plant without delay in order to avoid mold growth, and for the same reason the tomatoes should be utilized immediately upon arrival at the plant.

The first and probably the most important requisite to success in tomato products manufacture is the use of sound raw material. The manufacturer must be particularly careful in the inspection of deliveries of tomatoes following heavy rains or during prolonged periods of damp weather. Rains cause splitting of the fruit with subsequent rapid development of mold. High "mold counts" were once the most frequent cause for rejection or condemnation of tomato products, but content of worm and insect fragments has assumed greater prominence recently.

Washing.—The tomatoes should be thoroughly washed before sorting because the work of the sorters is thereby made more effective. Any of the devices described for washing tomatoes for canning may be used but the rotary washer is the most effective.

According to B. J. Howard of the U. S. Department of Agriculture, a rotary, heavy-wire, or fluted sheet-metal cylindrical washer, inclined at an angle of about 1 ft. in 8 and equipped with an abundance of water under heavy pressure, should be used. The screen, or fluted surface, causes the tomatoes to roll, whereas they may merely slide if the cylinder is made of perforated sheet metal. He states that a cylinder 2 to $2\frac{1}{2}$ ft. in diameter and 8 ft. long and revolving at about 20 r.p.m. will satisfactorily wash about 2 bu. of tomatoes per minute. Many rotary washers are larger than this and of correspondingly greater capacity.

Simple agitation in water is not satisfactory, because tomatoes often carry, in cracks and in the stem cavity, mold filaments which agitation does not dislodge and which appear later in the finished product where they can be found by the microscope of the food inspector or buyer. Heavy sprays of water will remove a large proportion of such mold filaments and small areas of soft rot not seen by the trimmers and sorters. Sprays more effectively remove adhering clay, dried particles of pulp, etc., from the skins of the tomatoes than does mere agitation in water.

The first requirement of a satisfactory tomato washer is water under heavy pressure (50 to 100 lb. per square inch) driven against the tomatoes in sprays. Agitation during spraying is the second essential.

Efficient and effective washing is one of the most important steps in the manufacture of tomato products, and the mold content of the finished article is dependent in a very marked degree upon this operation, because, as was stated above, the tomatoes are not peeled before pulping.[1]

Sorting.—Howard, who has shown the great importance of careful sorting, makes the following statement:

> A careful consideration of the causes of failure in making clean, sound, sanitary tomato products shows clearly that more difficulty is experienced in effecting sanitary washing, prompt handling and efficient sorting than in any of the other phases of the manufacturing process. Sorting is the most important of these operations, in which judgment of the operator plays an important part. Satisfactory washing is largely a question of proper operation of a mechanical device. This may be said of many of the other operations about the factory, but so far no mechanical device for separating the decayed from the good parts of tomatoes has been placed on the market. This operation must still be performed by hand. In the making of pulp of any kind, efficient sorting is absolutely necessary.

Since sorting is so important, greater care should be exercised in the selection of sorters than in selecting workers for any other operation.

Because of the close attention necessary, this work is very fatiguing, and the workers should be employed in short shifts of not over 3 hr. each. Sorting should be in charge of an experienced person who has proved his or her efficiency in this work and who is alert and discriminating as well as able to tactfully direct the other workers.

Sorting Systems.—Various sorting systems are in use. These may be designated as (1) table, (2) simple apron, and (3) divided apron.

In using the table system of sorting, the tomatoes are dumped upon a stationary table from the box or basket. The badly decayed tomatoes are rejected and small pieces of rot are trimmed from the fruit. The sound tomatoes are placed in suitable containers, such as buckets or pans, and transferred to the washer. The work of individual sorters can be effectively observed and controlled where this system is used, but it is usually more expensive than other methods.

In the simple-apron sorting system the tomatoes are carried on a broad and slowly moving belt before the sorters, who remove unfit material and permit the sound fruit to pass over the end of the belt to the washer and pulping machines. Theoretically the tomatoes are subjected to as many sortings as there are workers at the apron, and this is practically true if the speed of the belt is not too great, if the belt is not overloaded, if the

[1] The writer is greatly indebted to B. J. Howard of the U. S. Department of Agriculture, Bureau of Chemistry, for much of the material presented on washing and sorting of tomatoes and on plant sanitation.

sorters are efficient, and if the apron is properly lighted. The apron should be narrow enough for the sorters to reach across the entire width, the most convenient width being about 18 to 20 in.

In the divided-apron system the tomatoes are placed upon a conveying apron divided by lengthwise partitions into three alleys. The tomatoes are carried in the two outside sections. The sorters place the sound fruit in the central section and allow the unfit material to pass over the end of the belt through the outside sections. In some cases the rotten fruit is placed on the central conveyer and the sound fruit in the outside sections. Practically every tomato must be handled and, although an effective method of sorting, it is more expensive to operate than the simple apron.

Proportion of Moldy Fruit to Be Removed.—Howard, in reporting the results of 100 tests in 30 factories east of the Mississippi River, states that the proportion of moldy tomatoes (wholly or in part) in unsorted fruit varied from 0.4 per cent to 81 per cent and that the average was about 25 per cent. This means that about 58 tomatoes must be removed or trimmed from each bushel.

Rate of Movement of Apron.—The speed of the apron should be slow enough for the sorters to recognize and remove or trim all tomatoes containing rot and should not exceed 25 ft. per minute. Howard reports speeds of from 16 to 140 ft. per minute in various factories.

Volume of Fruit Sorted.—A bushel of tomatoes (about 60 lb.) covers, according to Howard, from 7 to 12½ sq. ft. and an average of about 9⅓ sq. ft. Experience has shown that not more than one-half of the area of the belt should be covered in order to permit effective sorting. Therefore, a space of at least 18½ sq. ft. should be allowed for each bushel in designing the sorting belt for a given plant. A belt 18 in. wide and moving at a rate of 25 ft. per minute would have, on this basis, a capacity of about 120 bu. per hour, or 1,200 bu. (36 tons) per 10 hr., and would require the services of six sorters.

Under average conditions of table sorting, one sorter can care for 5 to 8 bu. (about 300 to 500 lb.) per hour and in apron sorting 20 to 25 bu. per hour. A rate of 25 bu. per hour should be considered the maximum for efficient sorting.

The tomatoes should be fed to the sorting belt at a uniform rate of speed. The custom, observed in some factories, of dumping several boxes of tomatoes on the apron at irregular intervals causes the belt to be overloaded for short periods and empty during the interval between dumpings. Fairly satisfactory feeding hoppers are now obtainable and should be used to regulate the rate of flow of tomatoes to the apron. The tomatoes should not be heaped on the belt, but should be only one layer deep and not crowded tightly together.

Turning.—In many factories the sorting aprons are equipped with turning devices which automatically turn the tomatoes so that all portions of the surface of the fruit can be inspected by the sorters. One form of turning device consists of several pieces of water pipe, $\frac{3}{4}$ to 1 in., about 7 in. long, suspended from a steel rod above the sorting apron. The pipes are free to swing in the direction of flow of the apron. As the tomatoes pass beneath the pieces of pipe, the weight of the latter is sufficient to turn the fruit.

Howard has found that not more than 50 per cent of the area of the apron should be covered with tomatoes in order to give space for the tomatoes to be turned properly. On rubber or canvas belts there is a tendency for the tomatoes to slip instead of to turn, and the turning device operates more satisfactorily on woven metal conveyers (see Fig. 67).

Importance of Proper Lighting.—The speed and efficiency of sorting depend to a marked degree upon the lighting of the sorting belt. Effective sorting cannot be done if the sorting apron is located in a poorly lighted corner of the factory or if artificial light is not used on foggy or cloudy days. The lights should be directly above the sorting belt and so placed that the shadows of the workers do not fall upon the fruit.

Effect on Quality of Sorting.—Howard has found that the percentage of rotten material in tomatoes delivered to a large number of plants under his observation has varied from practically 0 to over 30 per cent and that the average was about 5.5 per cent. The percentage of rot in the sorted product varied from practically 0 to over 7 per cent, with an average of about $1\frac{1}{3}$ per cent. By careful sorting, material should be considerably below this average, and at no time should it exceed 1 per cent.

The proportion of rot is determined by weighing samples of 20 to 50 lb. of the sorted tomatoes direct from the belt and by trimming out and weighing objectionable portions.

Trimming.—Many of the tomatoes removed by the sorters can be trimmed and the sound portions of the fruit salvaged.

The canner, however, must not be too zealous in his attempt to salvage by trimming, or he may badly damage the quality of his finished product. Enough of the tomato must be cut away to insure complete removal of rot and flesh which has absorbed a disagreeable flavor from the adjacent rot.

Coring.—Since inauguration of maximum tolerance for worm- and insect-fragments content of tomato products, many canners now remove the cores from tomatoes to be used for purée, catsup, etc., since frequently small worms are at work in the flesh or stem in or near the core. Coring, incidentally, greatly reduces the mold content of the product.

Use of Peels and Cores.—If tomatoes used in canning are very carefully sorted and trimmed before scalding, the cores and peels may be

used for the preparation of purée, but the sorting to be effective must be done before scalding and cannot be done satisfactorily by the peelers.

Attempts have been made to wash the rot from peels and cores from unsorted fruit, but besides being very ineffective, this results in great loss of tomato juice and pulp.

It is impossible to sort out rotten material from peels and cores and, furthermore, such an attempt contaminates the whole mass of material with soft rot from badly decayed portions.

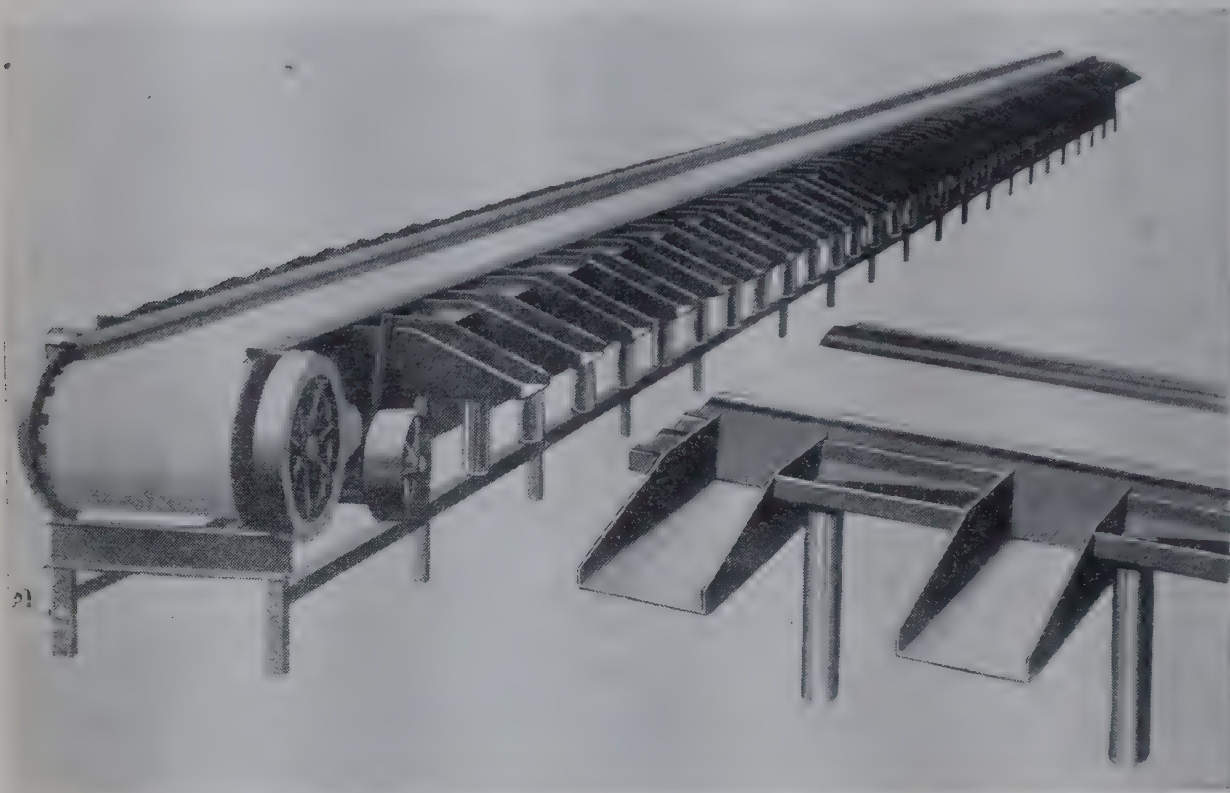

FIG. 67.—Tomato sorting and peeling belt. (*Courtesy Food Machinery Corp.*)

Pure food and drug officials state that in the majority of cases brought in the past against tomato products, the goods involved were made from trimmings, *i.e.*, peels and cores.

Howard recommends not less than one-eighth as many sorters and trimmers as peelers, if peels and cores are to be used for tomato products.

Pulping.—The sorted and trimmed tomatoes are converted into pulp by means of a machine commonly known as a "cyclone" or pulper. The machine usually consists of a heavy copper, monel, stainless steel, or bronze perforated sheet or screen in the form of a half cylinder which forms the lower half of the cylinder of the pulping machine. The upper half of the cylinder is of wood or heavy sheet copper. Heavy paddles revolve at a high rate of speed within the cylinder, and the tomatoes are broken by impact of the paddles or by being thrown against the walls of the pulper. The pulp and juice pass through the screen into a tank, and the skins, seeds, and fiber pass out through an opening at the

lower end of the pulper. The tomatoes enter the pulping cylinder through a hopper, usually fed by a continuous conveyer, and the mixture of pulp and juice is pumped to the concentrating kettles or other equipment (see Fig. 68).

Another pulper consists of an upright cylindrical screen against which the tomatoes are thrown violently by centrifugal force.

Heating.—In most factories the present custom is to convey the washed, sorted, and trimmed tomatoes direct to the pulper without preliminary heating. In one system of hot pulping the whole tomatoes are conveyed to a "breaking tank" and cooked with steam coils until

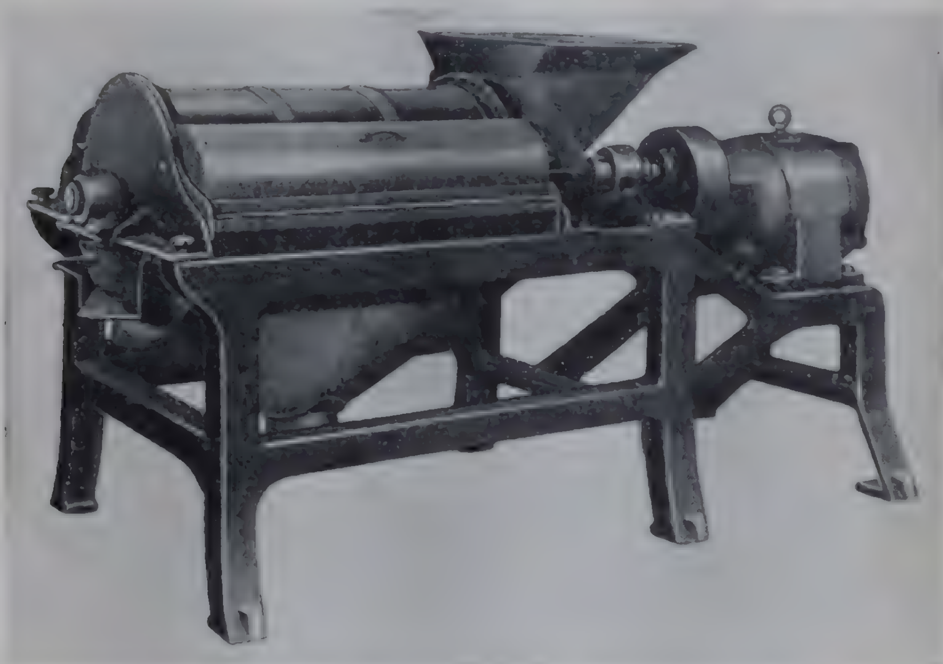

Fig. 68.—Tomato pulper. (*Courtesy Sprague Sells Corp.*)

thoroughly heated and softened. In some plants the tomatoes are crushed before heating, and the hot fruit is then pulped in the usual manner. This method gives a somewhat higher yield of pulp than is obtained by cold pulping and a pulp richer in pectin and gums, which increase the viscosity and decrease the tendency for the pulp and juice to separate. Catsup from hot pulped tomatoes will "stand up" and not spread when a drop of the catsup is placed upon a blotter, in sharp contrast to that from cold pulped tomatoes, which flattens and spreads quickly in the "blotter test."

It is doubtful whether hot pulping improves the color of the pulp, but it kills microorganisms and eliminates any increase in their number during normal operation of the plant. It also protects vitamin C.

Conveying Pulp to Concentrator.—Pumps should be made of bronze or other metals not acted upon to any marked degree by the acid of the tomatoes. Iron and steel become rusty and dissolve in the tomato juice to a sufficient extent to cause darkening of the color.

Pipes through which the pulp is conveyed should also be of material which does not injure the quality of the product. Glass-lined (enamel-lined) iron pipes are resistant to tomato acid and are easily cleaned. Block-tin pipes or silver-lined copper pipes have been successfully used. Wooden pipes have been used quite extensively but are difficult to clean and usually permit development of mold and bacteria during periods of idleness, with subsequent serious contamination of the pulp with these organisms.

Pipe lines should be cleaned thoroughly at the end of the day by flushing with water and by steaming. Before use in the morning, water should be pumped through them. Pipe lines, pumps, and certain other equipment are often prolific sources of infection if not cleaned frequently and thoroughly. Joints should be smooth and not permit of accumulation of pulp and growth of mold.

Concentration of the Pulp.—The raw pulp is too thin to be used without concentration and must be evaporated to the desired consistency before canning or using for tomato catsup or other tomato products.

Open Cookers.—Open kettles used for concentrating tomato pulp are made of wood, copper, tin-lined copper, or of glass-lined steel. The last-named material is readily cleaned and is becoming the most popular type of construction.

Open kettles are often not steam-jacketed but are heated by closed copper coils known as flash coils. The diameter of the usual flash coil is about 3 in. This relatively large diameter gives a large heating surface, allows free passage of the steam, and allows rapid and uniform heating of the coils, so that local overheating and sticking of the pulp are reduced to a minimum (see Fig. 69). Such a coil will under normal conditions reduce a charge of 500 gal. of pulp to one-half its original volume in 35 to 45 min., or less.

Wooden Tanks.—Cypress is most commonly used for wooden concentrators, but wooden tanks are apt to impart a musty or moldy flavor to the pulp unless kept clean and free from mold growth when not in use.

Metal Kettles.—Copper kettles are more expensive than wooden tanks or glass tanks equipped with flash coils and have the additional objection that the copper may injure the tomato color. Nickel and monel metal are both more desirable, although more costly than copper. Stainless steel of the proper composition is extremely resistant to corrosion and is therefore very desirable for cookers and also for pulper screens, filling equipment, etc., although costly.

Glass-lined Kettles.—So-called glass-lined tanks are constructed of an outer shell of steel, lined on the inside with heavy enamel, which is fused into the steel at a high temperature. The surface is smooth and easily washed, and the enamel is practically insoluble in the juice, and for

these reasons this equipment is rapidly displacing wood and copper. A common size for such tanks is about 1,100 gal., a convenient size for a 600-gal. batch of pulp.

Vacuum Pans.—Vacuum kettles are used in some plants, their principal advantage being in reduction of the boiling point to 160°F. or less, making it possible to retain the color and flavor of the tomatoes to a remarkable degree. They are, however, expensive in construction and require expensive vacuum pumps, large amounts of water for condensa-

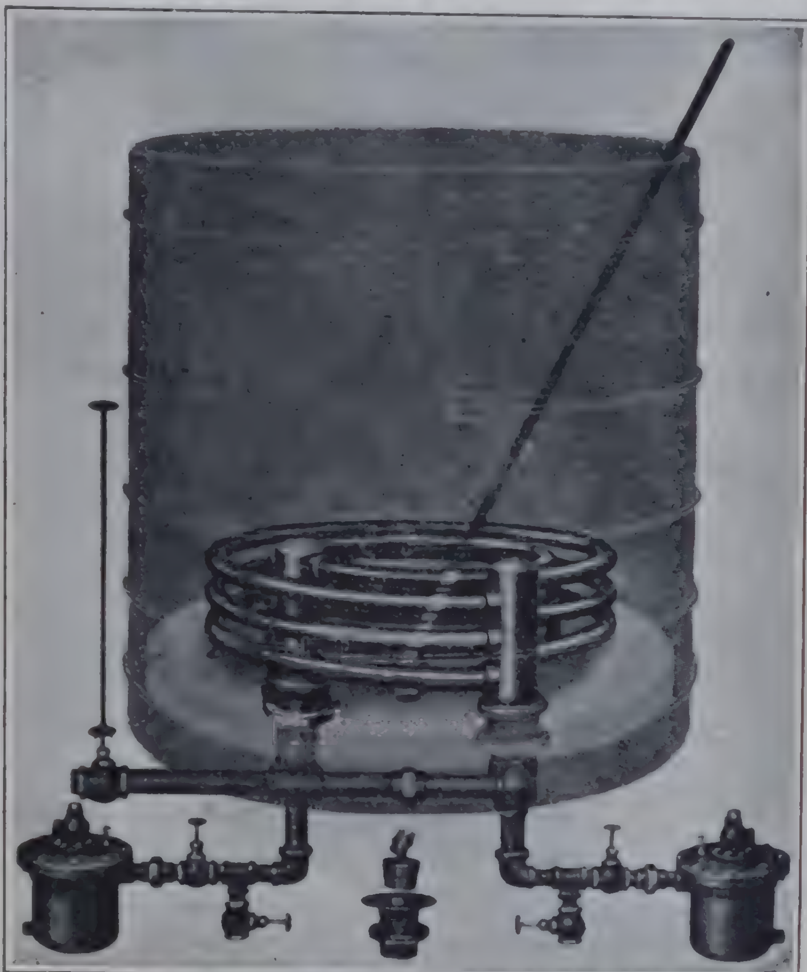

FIG. 69.—"Kookmor" flash coil for the concentration of tomato pulp. (*Courtesy Food Machinery Corp.*)

tion of the vapors evolved in boiling, and more expert knowledge and skill for operation than do open kettles. The construction and operation of vacuum pans will be found discussed at greater length in Chap. XVI.

Cooking the Pulp.—In order to prevent foaming and sticking of the pulp to the coils, some manufacturers of pulp add a small amount of cottonseed oil to the kettle, so that as the pulp rises during the filling of the kettle, the sides and coils are coated with oil. Foaming can, however, be avoided by careful heating and by occasionally spraying the surface of the boiling pulp with water.

As soon as the coil or steam jacket is covered, steam may be admitted and boiling started. During the first stages of boiling, the coil or jacket

must be well drained to prevent its filling with water, a condition which favors scorching.

Concentration must be accomplished rapidly in order to retain the bright-red tomato color and fresh flavor. A boiling of 30 min. is usually sufficient in a tank equipped with a good flash coil and an adequate supply of steam under high pressure.

Determining the Finishing Point.—Manufacturers of partially concentrated tomato pulp (purée) experience considerable difficulty in obtaining a finished product of uniform composition, and in determining accurately the point at which to stop the boiling process.

The pulp is usually concentrated to, and sold upon, a definite specific gravity, such as 1.035 or 1.04.

1 *Concentrating to Definite Volume.*—The boiling process is very short, and it is very difficult during boiling to make a determination of specific gravity which may be used to establish the end point of the boiling process accurately. Bigelow and Fitzgerald, therefore, recommend concentration of a measured volume of the raw pulp to a definite volume of concentrated purée. In boiling tanks with straight sides the volume may be determined by a measuring stick, due allowance being made for the volume occupied by the heating coil. A more accurate method is to calibrate the tank by adding measured volumes of water. The specific gravity and temperature of the raw pulp from the pulping machines are determined accurately. From these data and Table 50 the volume to which the pulp must be concentrated is determined.

If, for example, 100 gal. of raw pulp of specific gravity of 1.022 is measured into the kettle and the volume to which this pulp must be concentrated to reach a gravity of 1.035 is desired, it will be found by consulting Table 50 in the column headed "100 parts unconcentrated pulp at 86°F." and opposite 1.022 that the final volume should be, at 212°F., 63.3 gal. If the batch is 500 gal., then the final volume will be $5 \times 63.3 = 316.5$ gal.

If the operator desires to know how many gallons of raw pulp must be used to produce 100 gal. of finished concentrated pulp of 1.035, he would use Table 51. Thus for raw pulp of specific gravity of 1.022, 158 gal. will be required to yield 100 gal. of pulp of 1.035 gravity, and to produce 500 gal. of the concentrated pulp, $5 \times 158 = 790$ gal. of raw pulp would be required.

2 *By Specific Gravity.*—In some factories the specific gravity of the pulp during the boiling process is determined and the end point estimated on this basis. However, such rapidly made determinations are liable to be very inaccurate, for reasons noted below, or if done accurately, they cannot be made quickly enough to be of very great value to the operator of the kettle.

Other manufacturers merely concentrate until they feel certain that the product complies with the specifications and base their judgment entirely on the appearance and feel of the product. Such a hit-or-miss

TABLE 50.—VOLUME OF TOMATO PULP AT 212°F. RESULTING FROM THE EVAPORATION OF 100 PARTS OF UNCONCENTRATED PULP
(Specific gravity of concentrated pulp at 68°F., 1.035)
(*After Bigelow and Fitzgerald*)

Specific gravity of unconcentrated pulp at 68°F.	Volume at 212°F. of pulp of specific gravity 1.035 at 68°F.							
	100 parts unconcentrated pulp at 68°F.	100 parts unconcentrated pulp at 77°F.	100 parts unconcentrated pulp at 86°F.	100 parts unconcentrated pulp at 95°F.	100 parts unconcentrated pulp at 104°F.	100 parts unconcentrated pulp at 122°F.	100 parts unconcentrated pulp at 140°F.	100 parts unconcentrated pulp at 158°F.
1.0170	47.9	47.8	47.7	47.7	47.6	47.4	47.1	46.9
1.0175	49.5	49.4	49.3	49.3	49.2	49.0	48.7	48.5
1.0180	51.1	51.0	50.9	50.9	50.8	50.6	50.3	50.1
1.0185	52.6	52.5	52.4	52.4	52.3	52.0	51.8	51.5
1.0190	54.2	54.1	54.0	54.0	53.9	53.6	53.4	53.1
1.0195	55.8	55.7	55.7	55.6	55.5	55.2	55.0	54.7
1.0200	57.3	57.3	57.2	57.1	57.0	56.7	56.5	56.1
1.0205	58.9	58.8	58.8	58.7	58.6	58.3	58.1	57.7
1.0210	60.4	60.3	60.3	60.2	60.1	59.8	59.5	59.2
1.0215	61.9	61.9	61.8	61.7	61.6	61.3	61.0	60.7
1.0220	63.4	63.3	63.3	63.2	63.0	62.7	62.5	62.2
1.0225	65.0	65.0	64.9	64.8	64.7	64.4	64.1	63.8
1.0230	66.7	66.6	66.5	66.4	66.3	66.0	65.7	65.3
1.0235	68.2	68.1	68.0	67.9	67.8	67.5	67.2	66.8
1.0240	69.7	69.6	69.5	69.4	69.3	69.0	68.7	68.3
1.0245	71.3	71.2	71.1	71.0	70.9	70.6	70.3	69.9
1.0250	72.8	72.7	72.6	72.5	72.3	72.1	71.8	71.4
1.0255	74.3	74.3	74.2	74.0	73.9	73.6	73.3	72.9
1.0260	75.9	75.8	75.7	75.5	75.4	75.1	74.8	74.3
1.0265	77.4	77.3	77.2	77.1	76.9	76.6	76.3	75.8
1.0270	78.9	78.8	78.7	78.6	78.4	78.1	77.7	77.3
1.0275	80.5	80.4	80.3	80.2	80.1	79.7	79.4	78.9
1.0280	82.0	81.9	81.8	81.7	81.6	81.2	80.9	80.4
1.0285	83.6	83.5	83.4	83.2	83.1	82.8	82.4	81.9
1.0290	85.2	85.1	85.0	84.9	84.7	84.4	84.0	83.5

method is certain to be extremely unreliable not only because of the human equation but also because of the variation in the texture and appearance of pulps of the same specific gravity and because of the simi-

larity of appearance and texture of pulps of different specific gravities. If concentrated too far, specifications will be exceeded and a low yield obtained; if not concentrated sufficiently, the producer will be penalized by the purchaser. Therefore, accurate control of specific gravity is essential.

In addition to measuring the raw and concentrated pulps, the manufacturer must make accurate determinations of the specific gravity of each finished lot of pulp in order that he may know whether it is of the desired density.

TABLE 51.—VOLUME OF UNCONCENTRATED PULP REQUIRED TO PRODUCE 100 PARTS OF TOMATO PULP AT 212°F.
(Specific gravity of concentrated pulp at 68°F., 1.035)
(*After Bigelow and Fitzgerald*)

Specific gravity of unconcentrated pulp at 68°F.	Volume of unconcentrated pulp at designated temperature required to produce 100 parts of tomato pulp of s.g. 1.035							
	68°F.	77°F.	86°F.	95°F.	104°F.	122°F.	140°F.	158°F.
1.0170	208.8	209.2	209.6	209.6	210.1	211.0	212.3	213.2
1.0175	202.0	202.4	202.8	202.8	203.3	204.1	205.3	206.2
1.0180	195.7	196.1	196.5	196.5	196.9	197.6	198.8	199.6
1.0185	190.1	190.5	190.8	190.8	191.2	192.3	193.1	194.2
1.0190	184.5	184.8	185.2	185.2	185.5	186.6	187.3	188.3
1.0195	179.2	179.5	179.5	179.9	180.2	181.2	181.8	182.8
1.0200	174.5	174.5	174.8	175.1	175.4	176.4	177.0	178.3
1.0205	169.8	170.1	170.1	170.4	170.6	171.5	172.1	173.3
1.0210	165.6	165.8	165.8	166.1	166.4	167.2	168.1	168.9
1.0215	161.6	161.6	161.8	162.1	162.3	163.1	163.9	164.7
1.0220	157.7	158.0	158.0	158.2	158.7	159.5	160.0	160.8
1.0225	153.8	153.8	154.1	154.3	154.6	155.3	156.0	156.7
1.0230	149.9	150.2	150.4	150.6	150.8	151.5	152.2	153.1
1.0235	146.6	146.8	147.1	147.3	147.5	148.1	148.8	149.7
1.0240	143.5	143.7	143.9	144.1	144.3	144.9	145.6	146.4
1.0245	140.3	140.4	140.6	140.8	141.0	141.6	142.2	143.1
1.0250	137.4	137.6	137.7	137.9	138.3	138.7	139.3	140.1
1.0255	134.6	134.6	134.8	135.1	135.3	135.9	136.4	137.2
1.0260	131.8	131.9	132.1	132.5	132.6	133.2	133.7	134.6
1.0265	129.2	129.4	129.5	129.7	130.0	130.5	131.1	131.9
1.0270	126.7	126.9	127.1	127.2	127.6	128.0	128.7	129.4
1.0275	124.2	124.4	124.5	124.7	124.8	125.5	125.9	126.7
1.0280	122.0	122.1	122.2	122.4	122.5	123.2	123.6	124.4
1.0285	119.6	119.8	119.9	120.2	120.3	120.8	121.4	122.1
1.0290	117.4	117.5	117.6	117.8	118.1	118.5	119.0	119.8

Table 52 gives the factor necessary to correct the specific gravity of pulp determined at other temperatures than 68°F.

TABLE 52.—CORRECTIONS FOR THE SPECIFIC GRAVITY OF TOMATO PULP AT VARIOUS TEMPERATURES TO 68°F.

(*After Bigelow and Fitzgerald*)

To be subtracted from observed specific gravity

Temperature		Correction factor	Temperature		Correction factor	Temperature		Correction factor
Degrees F.	Degrees C.		Degrees F.	Degrees C.		Degrees F.	Degrees C.	
50	10.0	0.0016	56	13.3	0.0011	62	16.7	0.0007
51	10.6	0.0015	57	13.9	0.0010	63	17.2	0.0005
52	11.1	0.0015	58	14.4	0.0009	64	17.8	0.0004
53	11.7	0.0014	59	15.0	0.0009	65	18.3	0.0003
54	12.2	0.0013	60	15.6	0.0008	66	18.9	0.0002
55	12.8	0.0012	61	16.1	0.0008	67	19.4	0.0001
To be added to observed specific gravity								
69	20.6	0.0001	75	23.9	0.0009	81	27.2	0.0017
70	21.1	0.0002	76	24.4	0.0010	82	27.8	0.0018
71	21.7	0.0003	77	25.0	0.0011	83	28.3	0.0020
72	22.2	0.0004	78	25.6	0.0012	84	28.9	0.0021
73	22.8	0.0006	79	26.1	0.0014	85	29.4	0.0023
74	23.3	0.0007	80	26.7	0.0015	86	30.0	0.0025

By Refractometer.—Most canners now determine the end point by use of an Abbe refractometer, as described later in this chapter. It is rapid, dependable, and accurate.

Concentration by Draining Off of Juice.—At one time it was common practice to place the freshly prepared raw pulp in settling tanks, in which the insoluble solids rose to the surface and the juice separated in a clear layer in the bottom of the tank. This juice (termed "water" by the canner) was drawn off and discarded, and only the upper portion containing the solids was used. Bigelow has shown that the juice is just as rich in dissolved solids as the pulp itself and that discarding it results in very serious lowering of yield and in injury to quality. This practice has long since been discontinued.

Specific Gravity Methods.—Several methods are in use in tomato products factories for the determination of specific gravity. The more important are given below.

Sprague Cup Method.—The most common method of determining the specific gravity of tomato pulp is by use of the Sprague cup and

balance. The cup is a conical copper vessel holding 1 liter. This is filled level full with boiling water, the outside is dried carefully, and the cup with contents is weighed. It is again weighed level full of the boiling hot pulp. The scale is so constructed that the weight of the empty cup is counterpoised, and the ratio of weight of the pulp to that of the water gives the specific gravity of the pulp.

In filling the cup, the pulp cools somewhat, which will cause its specific gravity to increase. Air may be trapped in the pulp and cause it to weigh less than it should. Although these are compensating errors, one or the other frequently causes very serious inaccuracies in the determination. Bigelow and Fitzgerald have found that very much more reliable results are obtained by immersing the cup in the hot pulp in the boiling tank and leveling off the surface of the pulp at once. This reduces to a minimum both the errors noted above. The principal merits of the method are rapidity and simplicity.

In determining the specific gravity of cold pulp, this same apparatus may be used. Here, however, entrapped air becomes a very serious source of errors, and the cup and contents must be centrifuged several minutes to expel air before the weighing is made.

Pycnometers.—Special heavy-walled small bottles or pycnometers, weighed on an analytical balance, are now used by many chemists in preference to the metal cup described above (for use of pycnometers for tomato products, see Cruess and Christie's "Laboratory Manual").

By Hydrometer.—Because of the thick consistency of tomato pulp, it is difficult to obtain accurate hydrometer readings on the unfiltered pulp. Nevertheless Hier states that he finds the hydrometer very good for plant control purposes.

Bigelow and Fitzgerald have found that the juice from the hot pulp may be quickly filtered through a cheesecloth to give a filtrate practically free from suspended solids. The specific gravity or Brix of the filtrate can then be determined with speed and accuracy. The temperature also is taken and suitable correction made, or the filtrate is chilled in the cylinder by packing it in crushed ice and the reading is taken at the standard temperature of 20°C. (68°F.) They have established the relation between the hydrometer reading so obtained, the specific gravity of the unfiltered pulp, and the total solids by drying to constant weight *in vacuo* at 70°C. (158°F.) as shown in Table 53.

Canners report that the method gives good results in practice and is rapid and dependable, although it is recommended that the hydrometers used be checked each season against a standard method such as the pycnometer method. This is desirable because of the personal factor involved, the variation in hydrometers, variation in method of preparing pulp, and variation in the composition of the tomatoes themselves. Often a Brix instead of a specific gravity hydrometer is used.

By Weight of Dried Sample.—As indicated in Table 53, there is a definite relation between specific gravity and total solids determined by drying at 70°C. *in vacuo*. When dried in an oven at atmospheric pres-

TABLE 53.—RELATION BETWEEN TOTAL SOLIDS AND SPECIFIC GRAVITY OF TOMATO PULP AND FILTRATE
(*After Bigelow and Fitzgerald*)

Per cent solids in pulp	Specific gravity at 20°C.		Per cent solids in pulp	Specific gravity at 20°C.		Per cent solids in pulp	Specific gravity at 20°C.	
	Pulp	Filtrate		Pulp	Filtrate		Pulp	Filtrate
3.42	1.0150	1.0133	7.06	1.0297	1.0274	10.41	1.0433	1.0404
3.53	1.0155	1.0138	7.17	1.0301	1.0279	10.52	1.0437	1.0409
3.64	1.0159	1.0142	7.28	1.0306	1.0283	10.64	1.0442	1.0413
3.76	1.0163	1.0146	7.34	1.0308	1.0285	10.70	1.0444	1.0415
3.87	1.0168	1.0151	7.45	1.0313	1.0290	10.80	1.0449	1.0419
3.98	1.0172	1.0155	7.56	1.0317	1.0294	10.91	1.0453	1.0424
4.09	1.0177	1.0160	7.62	1.0320	1.0296	10.97	1.0456	1.0426
4.20	1.0181	1.0164	7.74	1.0324	1.0300	11.08	1.0461	1.0430
4.26	1.0183	1.0166	7.85	1.0329	1.0305	11.20	1.0465	1.0435
4.37	1.0188	1.0170	7.90	1.0331	1.0307	11.25	1.0467	1.0437
4.48	1.0192	1.0175	8.02	1.0336	1.0311	11.36	1.0472	1.0441
4.59	1.0197	1.0179	8.12	1.0340	1.0315	11.47	1.0476	1.0446
4.71	1.0201	1.0183	8.24	1.0345	1.0320	11.59	1.0481	1.0450
4.82	1.0205	1.0188	8.35	1.0349	1.0324	11.70	1.0485	1.0454
4.93	1.0210	1.0192	8.46	1.0354	1.0328	11.81	1.0490	1.0459
5.03	1.0215	1.0196	8.57	1.0358	1.0333	11.93	1.0494	1.0463
5.10	1.0217	1.0198	8.68	1.0363	1.0337	12.05	1.0499	1.0467
5.21	1.0222	1.0203	8.74	1.0365	1.0339	12.10	1.0501	1.0469
5.33	1.0226	1.0207	8.86	1.0370	1.0344	12.21	1.0505	1.0474
5.44	1.0230	1.0211	8.96	1.0374	1.0348	12.32	1.0510	1.0478
5.55	1.0235	1.0216	9.14	1.0381	1.0354	12.43	1.0515	1.0482
5.66	1.0240	1.0220	9.25	1.0386	1.0359	12.55	1.0519	1.0487
5.77	1.0244	1.0225	9.36	1.0390	1.0363	12.65	1.0524	1.0491
5.88	1.0249	1.0229	9.47	1.0395	1.0368	12.77	1.0528	1.0495
5.94	1.0251	1.0231	9.58	1.0400	1.0372	12.88	1.0533	1.0500
6.05	1.0256	1.0235	9.70	1.0404	1.0376	12.99	1.0538	1.0504
6.16	1.0260	1.0240	9.80	1.0408	1.0381	13.10	1.0542	1.0508
6.22	1.0263	1.0242	9.92	1.0413	1.0385	13.22	1.0547	1.0513
6.33	1.0267	1.0246	10.02	1.0417	1.0389	13.32	1.0551	1.0517
6.45	1.0272	1.0251	10.14	1.0421	1.0394	13.44	1.0556	1.0521
6.50	1.0274	1.0253	10.25	1.0426	1.0398	13.55	1.0560	1.0525
6.61	1.0279	1.0257	10.35	1.0430	1.0402	13.66	1.0565	1.0529
6.72	1.0283	1.0261	.....	......	......	13.78	1.0569	1.0533
6.84	1.0288	1.0266	.....	......	......	13.89	1.0574	1.0537
6.95	1.0292	1.0270	.....	......	......	14.01	1.0579	1.0241

sure, tomato products decompose rather rapidly and results for moisture so obtained will be too high.

The official method for this determination is as follows:

Place from 2 to 4 grams of the well-mixed sample in an accurately weighed flat-bottomed dish about 2½ in. in diameter, spreading thinly. Accurately weigh dish and sample. Place in a vacuum and dry at 70°C. and 28 to 29 in. vacuum (inches of mercury) for 4 hours. Remove and weigh immediately.

In the absence of a vacuum oven 10 grams of the sample is evaporated to dryness in a broad shallow dish over a steam bath. It is then dried in an oven at 95 to 100°C. (203 to 212°F.) for 4 hr. and weighed. The per cent of solids thus obtained is multiplied by 1.085 to give the true percentage. This method is not so accurate as drying *in vacuo* but will serve for factory control.

By Refractometer.—In recent years the methods previously described have been supplanted to a very great extent by the Abbe refractometer. This instrument consists of two prisms between which a few drops of the sample is placed; a mirror which reflects light upward through the prisms; a telescope with cross hairs; a scale reading in refractive index or in degrees Brix or both; and a compensator to correct for chromatic dispersion of the light. The prisms are surrounded by water jackets through which water may be circulated to maintain a constant temperature, the usual standard temperature for this instrument being 20°C. (68°F.). If the temperature at which the reading is made is other than 20°C. add 0.0001 to the observed refractive index for each 1°C. above 20°C. or subtract the same quantity for each 1°C. below 20°C. With use it is occasionally necessary to adjust the instrument. Its "zero setting" is easily checked by determining the refractive index of distilled water; this at 20°C. is 1.3330. By allowing water from the cannery water main to flow through the jackets of the prism, they may be maintained at a fairly constant temperature.

In using the instrument for factory control, a sample of the hot product is taken from the kettle; a 10-cc. pipette is filled with the hot pulp, cooled under the water tap, and wiped free of water; the bottom portion is discarded; the prisms are closed; the tip of the pipette is placed against the funnel-shaped hole on the side of the prisms; and a drop or two of the sample is allowed to flow in between the prisms. The liquid that flows into the orifice leaves behind much of its solid pulp, giving a reasonably clear layer between the prisms. Or more commonly, 25 or 30 cc. of the sample is poured into a small Erlenmeyer flask and cooled quickly under a water tap; a drop is removed by a spatula or rubber-tipped glass rod; it is placed on the open prism; the prisms are closed; and the reading is taken. A somewhat clearer reading is obtained if the cooled

pulp is strained through a small piece of cheesecloth and a drop of the strained liquid placed between the prisms. If cold water is circulating through the jackets of the prisms, the drop of sample quickly assumes the temperature of the instrument.

The prisms must be well cleaned with water and a soft cloth after each sample is read. As the glass of the prisms is very soft, great care must be taken to avoid scratching their surface.

For pulps containing up to 12 per cent total solids Bigelow and others (1934) give the following formula for calculating per cent solids of pulp from the refractive index:

$$\text{Per cent solids} = 4.00 + 691(n_D - 1.3382) + 1029(n_D - 1.3382)^2$$

For pulps ranging from 12 to 20 per cent solids the formula becomes

$$4.54 + 644(n_D - 1.3382) + 959(n_D - 1.3382)^2$$

In these formulas n_D is the observed refractive index.

The relation between refractive index and total solids content is markedly affected by the concentration of added salt, sugar, and acetic acid. Accordingly it is customary in most cannery laboratories to construct a large graph on coordinate paper with refractive index as abscissas and per cent solids determined by vacuum oven as ordinates; or a table showing the same information is constructed. In either case the product of the plant in question is used. By making accurate determinations of refractive index and total solids by vacuum oven on samples representing low, medium, and high total solids, the graph can be constructed easily as the relationship is practically a straight-line function; or a table can be constructed by extrapolation.

Readings can be made very rapidly; less than 1 min. being required for the actual reading, or less than 5 min. for cooling a sample of the hot pulp, mounting a drop between the prisms, and taking the reading.

The Abbe refractometer is made by all leading instrument manufacturers and is a commonly used instrument in sugar laboratories.

Finishing.—Tomato purée should be smooth in texture and fine-grained. The pulping machine allows relatively large pieces of pulp and some fiber to pass through the screens, and cooking coagulates or granulates the pulp more or less. It is, therefore, customary, before canning the purée, to pass it through a finisher to improve the texture.

A finisher consists of a horizontal cylinder or a vertical cone made of a fine sieve of bronze, stainless steel, or monel metal, inside of which are heavy bristle brushes which revolve rapidly, causing the fine pulp to pass through the screen and the pieces of skin, seeds, fiber, etc., to pass out the end of the machine.

Canning and Sterilizing.—If for household use, the purée should be canned in No. 1 or No. 2 cans; if for sale to large users, it is canned in No. 10 or in 5-gal. cans. As a matter of fact, little purée is canned for home use; most of it is packed on order for manufacturers of soup or catsup or for use by hotels, restaurants, and institutions.

The No. 10 and smaller cans are usually filled by a rotary automatic filler at 170 to 185°F. and sealed hot, generally no exhaust being necessary. The filled small cans are sterilized a short time in agitating cookers at 212°F. Number 10 cans usually need no further heating if filled and sealed scalding hot.

The 5-gal. cans are filled boiling or scalding hot (180°F. or above) and are sealed at once with a soldering steel and cap. Most packers do not process the filled cans but rely upon the temperature of the hot pulp for sterilization. The 5-gal. cans are made of very heavy tin plate and with care can be used several seasons, provided the cans are rinsed thoroughly with hot water after opening and are dried at once to prevent rusting. These cans, particularly filled cans, must be handled carefully to avoid development of leaks.

At one time 50-gal. barrels were used generally for pulp, sodium benzoate or distilled vinegar being used as preservatives; or the barrels were filled hot and sealed without addition of preservatives. This practice is now no longer followed because of the frequent growth of mold and bacteria in the barrels with consequent frequent and costly condemnation by pure food officials.

Lot Records.—The canner should stack each lot of pulp separately and give it a number or other mark of identification in order that goods below standard may be segregated from the better grades. A complete record of each lot should be kept, the record to contain data on quality, treatment of raw material, specific gravity, microscopical examination, and notes on any deviations from the usual procedure. Records of this type are very valuable in locating causes of trouble in the plant.

Cooling.—Tomato purée is a poor conductor of heat and, if stacked hot, is very apt to develop a brown color and scorched flavor through "stack burning." The cans should be promptly and thoroughly cooled after processing.

TOMATO PASTE

Tomato paste is a staple article of diet in Italy where it is used very generally under the name of *Salsa di Pomodoro* as a flavoring for many Italian dishes. It is a pasty, semisolid product of about the consistency of heavy apple butter, and present standards require it to contain at least 22 per cent total solids when dried to constant weight *in vacuo* at 70°C. Concentrated tomato paste must contain at least 33 per cent total solids as determined by drying *in vacuo* at 70°C. Being highly concen-

trated, tomato paste is economical in its use of space and is not costly to transport.

In one large tomato paste factory in California the pulp is concentrated to a heavy consistency in vacuum pans. The hot pulp is then transferred to an open-jacketed kettle equipped with a revolving stirring and scraping device and is concentrated to the desired final density. It is filled into 6-oz. cans and sealed hot. Usually no sterilization is required, unless the paste has cooled considerably before filling.

One European method consists in storing the raw pulp in tanks or barrels several days to allow fermentation to occur. The pulp rises to the surface and the "water" is discarded. The pulp is drained in bags and is then mixed with a small amount of salt and spread in the sun to dry sufficiently to check molding. Olive oil and garlic may be added.

In another method observed by the writer and in use in a small California factory, the pulp was boiled to a pasty consistency in a vacuum pan. The product was then dried in the sun on fruit trays. A similar method, according to Howard, is used in Italy.

The last two methods yield products high in counts of microorganisms and usually will not pass the pure food standards.

TOMATO CATSUP

Tomato catsup is the most popular condiment used in the United States and a very large quantity of tomatoes is used in its manufacture.

Raw Materials.—In some cases the catsup is made direct from the raw pulp; in others the pulp is produced, concentrated, and canned in various tomato districts and is shipped to large catsup plants for conversion into finished catsup.

In any case, only clean wholesome tomatoes of intense red color and of meaty, not watery, texture should be used. High acidity and a rich tomato flavor are additional desirable qualities.

Preparation of the Pulp.—The principles of preparing purée apply with equal or greater force to the preparation of pulp for catsup. Catsup is a more highly concentrated product than the average purée and microorganism counts are thereby increased more or less proportionately, a factor which must be taken into consideration in selecting, sorting, washing, and otherwise preparing the pulp for catsup.

The tomatoes are in most factories pulped cold, but it has been proved that boiling the tomatoes before pulping extracts pectin from the seed coats and skins, causing the catsup to be of thicker consistency and to respond favorably to the "blotter" test.

In some factories the pulp is concentrated to a specific gravity of about 1.058 to 1.06 before use in catsup; in others the raw fresh pulp or pulp of 1.035 or 1.04 specific gravity is employed.

Spices and Condiments.—Catsup contains various spices in addition to sugar, salt, and vinegar; the character of commercial catsups varies largely according to the kinds and proportions of spices used.

Cloves should be of the headless type, because the clove heads carry a large amount of tannin, which dissolves in the catsup or vinegar and may combine with iron salts to cause darkening. Penang cloves are most popular.

Cinnamon is used in broken stick form, Saigon cinnamon being usually recommended. Mace from Penang or Banda is usually specified in preference to that from other districts.

Cayenne and onions are desired for their pungency rather than for other qualities. Hot onions are preferred to mild ones, the same being true of cayenne.

Distilled vinegar, rather than cider vinegar, is used for catsup because a strong vinegar (of 10 per cent acetic acid) is desired. If cider vinegar were used, it would be necessary to concentrate the catsup considerably to expel its excess water.

Salt and sugar should be of high quality.

Paprika is sometimes added to intensify the red color of the catsup but adds very little to the flavor.

Extraction of Spices.—Spices are often added as a vinegar extract of the whole or coarsely broken spices, prepared by adding the spices to distilled vinegar and steeping at or near the boiling point in a covered wooden or glass-lined tank for 2 or 3 hr. The vinegar is then separated from the spices and is added to the pulp in the catsup kettle.

In some factories the onions, garlic, and spices are tied in bags, and hung in the boiling catsup for extraction of flavors and essential oils. The spices retain some oil after the boiling process and can be used a second time if fresh spices are also added. Campbell gives the analyses

Table 54.—Analyses of Cinnamon and Cloves before and after Extracting
(*After Campbell*)

	Cinnamon		Cloves	
	Before boiling, per cent	After boiling, per cent	Before boiling, per cent	After boiling, per cent
Total ether extract	7.20	3.80	30.50	14.40
Fixed oil	3.90	2.65	12.55	8.00
Volatile oil	3.30	1.15	17.95	6.40
Ash	5.75	2.55	5.80	5.75

of cinnamon and cloves before and after such boiling as shown in Table 54.

Powdered spices have been added direct to the pulp for flavoring purposes, but these impart a dark color. The method, while satisfactory for home use, is unsuited to commercial practice.

Essential oils of cloves and other spices have been successfully used. Oil extracts and acetic acid extracts of spices may also be used.

Oleo resins, which are proprietary preparations consisting of concentrated volatile solvent extracts of spices in the form of resins or syrupy extracts, are sometimes used. These contain flavors and aromas in addition to those of the essential oils and should be superior for this reason to the latter for flavoring purposes. The resins are mixed with a sugar syrup before adding to the catsup.

Formulas.—A number of satisfactory formulas, of which the following is typical, are in commercial use

Heavy purée	100 gal. (specific gravity 1.06)
Salt	28 lb.
Sugar	125 lb.
Chopped onions	25 lb.
Cinnamon (broken bark)	25 oz.
Mace	3½ oz.
Whole cloves (headless)	15 oz.
Allspice	15 oz.
Cayenne	3½ oz.
Chopped garlic (optional)	4 oz.
Vinegar (distilled of 10 per cent acetic acid)	12 gal.
Paprika (ground, optional)	2 lb.

The spices (except paprika, onions, and garlic) are placed in the vinegar and cooked in a covered kettle about 2 hr. at the simmering point, and the sugar and salt may then be dissolved in the vinegar. The extract thus obtained, freed of the solid spices, is added to the catsup near the end of the boiling process. The paprika is added in powdered form directly to the catsup, if the manufacturer desires to use it. The above formula makes slightly more than 100 gal. of catsup.

If desired, the spices may be boiled in a bag with the purée and the chopped onions and garlic added direct to the tomato pulp. They can be separated from the catsup, after cooking, by means of a finisher.

Cooking.—The purée is boiled with the spices, salt, and sugar in order to concentrate the product to the desired consistency and to blend the various ingredients. The cooking is usually done in an open glass-lined tank equipped with a flash coil, although a vacuum pan, steam-jacketed copper kettle, or a wooden tank and copper flash coil may be used. As is the case with purée, a product of brighter color is obtained by cooking *in vacuo*.

The length of the boiling process depends upon the concentration of the purée used. If it is of 1.06 specific gravity, the boiling need last a very few minutes only; merely long enough to mix the vinegar, spice extract, sugar, and salt thoroughly. In such cases boiling is not continued long enough to permit adding spices to the catsup in a bag; a vinegar extract of the spices or essential oils or oleo resins must be used, and boiling should be slight after their addition, in order that loss of flavor and acetic acid may be avoided.

Many factories start with the raw nonconcentrated pulp and concentrate it in an open kettle. If this method is used, the spices may be placed in a bag in the pulp, and the long boiling required for concentration will extract the necessary flavors. It is desirable to add a portion (about one-third) of the sugar at the start of the boiling process as this tends to intensify and fix the tomato color. The salt is not added until near the end of the boiling process, because it tends to bleach the color and to cause solution of copper from the coil or kettle. Spice extracts, oils or oleo resins, and vinegar should be added near the end of the boiling period in order to avoid loss of volatile flavors such as essential oils and acetic acid. Approximately 3 gal. of raw pulp are required to make 1 gal. of purée of 1.06 specific gravity.

If salt is added directly to the boiling catsup, it should be scattered over the surface so that it will not sink to the bottom of the kettle and fail to dissolve.

Determining the Finishing Point.—The cooking process is continued until the desired consistency is obtained. The end point is determined in most factories by refractive index; although it is also customary to use a measured volume of purée and to condense this to a definite volume, which by experiment has been found to correspond to the final specific gravity desired; a refractive index or specific gravity reading is then made (see paragraphs on determining the specific gravity and refractive index of purée).

The following table, after Bigelow, Smith, and Greenleaf (1934) gives the relation between total solids and the refractive index of tomato catsups of average commercial composition. There will be some deviation from these values according to the tomatoes and formula used. The proportions of salt, sugar, and acetic acid affect the relationship of refractive index and total solids markedly.

For the catsup formula given earlier, a final specific gravity of approximately 1.145 to 1.165 will give a catsup of satisfactory consistency. This density corresponds to about 32 to 36 per cent total solids, a large proportion of which consists of sugar and salt.

Finishing.—Catsup should be smooth in consistency and free from large pieces of spices, onion, garlic, etc. Therefore, when the desired

specific gravity has been reached the hot catsup is passed through a finishing machine, which removes coarse material and overcomes any tendency of the product to become "grainy."

The acetic acid of the catsup attacks brass rather vigorously and for this reason the finisher screen should be made of more resistant metal, such as monel metal, bronze or stainless steel.

TABLE 55.—PER CENT TOTAL SOLIDS, SPECIFIC GRAVITY, AND ABBE REFRACTOMETER READING IN TOMATO CATSUP
At 20°C. (68°F.)
(*After Bigelow, Smith, and Greenleaf*)

Per cent total solids	Specific gravity	Refractive index at 20°C	Per cent total solids	Specific gravity	Refractive index at 20°C
16.0	1.067	1.3557	28.5	1.128	1.3767
16.5	1.069	1.3565	29.0	1.131	1.3775
17.0	1.072	1.3573	29.5	1.133	1.3784
17.5	1.074	1.3582	30.0	1.136	1.3793
18.0	1.077	1.3590	30.5	1.138	1.3802
18.5	1.079	1.3598	31.0	1.140	1.3811
19.0	1.082	1.3606	31.5	1.143	1.3820
19.5	1.084	1.3614	32.0	1.145	1.3829
20.0	1.087	1.3622	32.5	1.148	1.3838
20.5	1.089	1.3631	33.0	1.150	1.3847
21.0	1.091	1.3639	33.5	1.153	1.3856
21.5	1.094	1.3647	34.0	1.155	1.3865
22.0	1.096	1.3655	34.5	1.158	1.3874
22.5	1.099	1.3664	35.0	1.160	1.3883
23.0	1.101	1.3672	35.5	1.162	1.3893
23.5	1.104	1.3681	36.0	1.165	1.3902
24.0	1.106	1.3689	36.5	1.167	1.3911
24.5	1.109	1.3698	37.0	1.170	1.3920
25.0	1.111	1.3706	37.5	1.172	1.3930
25.5	1.113	1.3715	38.0	1.175	1.3939
26.0	1.116	1.3723	38.5	1.177	1.3949
26.5	1.118	1.3732	39.0	1.180	1.3958
27.0	1.121	1.3740	39.5	1.182	1.3968
27.5	1.123	1.3749	40.0	1.185	1.3978
28.0	1.126	1.3758			

Bottling.—The hot finished catsup is in some factories run by gravity direct into bottles which have been previously thoroughly washed and are scalding hot at the time of filling. In most plants the catsup is transferred from the finisher to a jacketed kettle above the filling machine.

where it is heated nearly to the boiling point before being filled into bottles. A short direct pipe connects the heating vessel with the filling machine, so that very little cooling of the catsup occurs during transfer to the bottle. A steam-jacketed glass-lined pipe may also be used instead of a kettle to heat the catsup before filling.

Pasteurizing.—If the catsup is heated to near the boiling point and is filled into hot sterilized bottles which are sealed immediately after filling, it is not necessary that the bottled catsup be sterilized or pasteurized. If, however, the temperature drops to 160°F. or less during the interval between finishing and bottling, it will be necessary, in most cases, to heat the catsup in the bottle in order to prevent spoilage.

A temperature of 180°F. for 45 min. is ordinarily considered a severe enough pasteurization for catsup filled at above 170°F. Catsup is a very poor conductor of heat, and the manufacturer should make heat penetration tests of his product in various sizes of bottles in order to adjust his pasteurizing time and temperature more intelligently.

If the catsup is not pasteurized, the filled and sealed bottles should be passed through a vat of hot water or beneath sprays of hot water to remove catsup adhering to the outside of the bottles; otherwise it will dry tightly to the bottles and be difficult to remove.

Canning.—Some catsup is canned in No. 10 lacquered cans, and if filled at about 180°F., no sterilization is necessary.

Sodium Benzoate.—At one time most catsup was preserved with $\frac{1}{10}$ per cent of sodium benzoate, and often its use was associated with catsup of extremely poor quality.

Sodium benzoate is not used at present in any of the leading brands of catsup. The present-day manufacturer depends upon the acetic acid of the vinegar and the preservative action of the spices to prevent spoiling after the bottle has been opened.

Yield.—For eastern conditions Campbell states that 44 bu. of tomatoes (60 lb. per bushel), or 2,640 lb., should yield about 264 gal. of purée of a specific gravity of 1.02, or 150 gal. of a specific gravity of 1.035, or 100 gal. of catsup of 25 per cent total solids. This corresponds to a yield of about 1 gal. of catsup from 2.64 gal. of fresh pulp. Yields in California are higher owing to higher specific gravity of the fresh pulp.

Spoilage.—Catsup is subject to two types of spoilage or deterioration, *viz.*, blackening near the surface and spoilage by microorganisms.

Blackening.—Investigation has shown that the blackening is caused by the formation of iron tannate and that the presence of air appears to be essential for the reaction.

Iron is dissolved in the ferrous condition from equipment coming in contact with the purée or catsup during manufacture or is dissolved by the acetic acid of the catsup from the metal of the bottle cap. In the

presence of air, which may be present in the bottle because of slack filling, or which may have entered the bottle through a faulty cap, oxidation of the iron to the ferric state takes place. The ferric salts combine with tannin, extracted from the spices or from the stems and seeds of the tomatoes, to form a black finely divided precipitate of iron tannate. The heads of cloves have been found to be rich in tannin; hence the advice to use headless cloves.

Caps should be lined with cork disks and these in turn faced with lacquered paper spots in order to preclude any possibility of the catsup coming in contact with the metal of the cap.

Spoilage by Microorganisms.—Carl S. Pederson and associates of the New York Agriculture Experiment Station and S. H. Ayers and associates of the Glass Container Association have conducted much research on the spoilage of tomato catsup by bacteria and yeasts.

Pederson found that most of the spoilage of bottled catsup in New York State was caused by nonspore-forming organisms belonging to six species of Gram-positive, lactic acid-forming organisms of the Lactobacillus and Leuconostoc genera. Five species formed gas abundantly in catsup and in sugar-containing media; one formed acid, but not gas. None of the organisms are very heat resistant; all were killed at 170°F. in a very few minutes.

Ayers found yeast in many fermenting bottles of catsup and concluded that in filling bottles with hot catsup the catsup in the neck may cool so quickly that organisms there may not be killed. Pasteurization after bottling is the remedy.

In California plants spoilage of catsup has not been serious. The high acetic acid content of catsup renders it easily sterilized by heat and resistant to spoilage by microorganisms after the bottle is opened. On this account the addition of a preservative such as sodium benzoate is not necessary. However, when opened bottles of catsup stand on a restaurant table for many weeks, being filled from a can of catsup from time to time, acid-resistant yeasts, molds, and bacteria frequently become established and partially spoil the product.

Antiseptic Action of Spices and Condiments.—It has been shown by K. G. Bitting that curry, ginger, mace, paprika, peppers, and sage possess little or no antiseptic value in preventing the growth of mold or yeast. Allspice, cinnamon, and cloves exhibit some antiseptic action on these organisms.

The active ingredients of these spices are the oils, extracted or added in the process of manufacture. Eugenol from the oils of allspice and cloves and cinnamic aldehyde from oil of cinnamon are stated to be the active ingredients. According to Mrs. Bitting these are present in very small concentrations in catsup, *e.g.*, approximately 1:138,000 and

1:259,000, and therefore exert very little antiseptic action. Hier states that 1.25 per cent acetic acid will preserve catsup at least 2 weeks under normal conditions, long enough to permit the catsup to be consumed on the average table after the bottle has been opened. Acetic acid appears to be the most active preservative in catsup and in this respect is probably much more important than the spices.

The amount of sugar used in catsup is not sufficient to exert any appreciable antiseptic effect, its principal purpose being to counteract the acid taste of the acetic acid.

CHILI SAUCE

Chili sauce is made from whole peeled tomatoes and is not pulped or passed through a finisher at any stage of the process. It is used in large quantities as a flavoring in cooking and to some extent as a table relish.

Preparation of Tomatoes.—The tomatoes are peeled and cored as for canning, the same care in washing, sorting, and trimming being taken as in preparing tomatoes for canning.

Flavoring.—Spices, onions, garlic, sugar, vingar, and salt are used in much the same manner as in catsup. Usually more cayenne, onions, and garlic are used than for tomato catsup.

In most California factories, the spices, onions, and garlic are added to the vinegar and an extract made as described for catsup. This is added to the tomatoes near the end of the boiling process. In many factories the chopped onions and garlic are added direct to the tomatoes and remain in the final product.

One formula is as follows:

Whole peeled tomatoes	840 lb.
Chopped onions	35 lb.
Whole allspice	½ lb.
Whole cloves (headless)	⅔ lb.
Cinnamon (stick)	2½ oz.
Mustard	⅔ lb.
Garlic (ground)	½ lb.
Distilled vinegar (of 10 per cent acetic acid)	5 gal.
Salt	14 lb.
Sugar	60 lb.

The spices, except the cayenne and mustard, are heated in a covered vessel to the simmering point in the vinegar for about 2 hr. and then strained. The peeled tomatoes are concentrated, preferably in a vacuum pan or glass-lined kettle, to about one-half their original volume with part (about one-third) of the sugar. The spiced vinegar, powdered cayenne, powdered mustard, salt, and the remainder of the sugar are added near the end of

the boiling process. The salt must be added slowly in order to make certain that it will dissolve, or it may, if desired, be dissolved in the vinegar.

Spices can be extracted in a cloth bag in the boiling tomatoes as described for catsup or may also be added in the form of oils or oleo resins.

Cooking.—The cooking is conducted in the same manner as for catsup and for the same purposes, *viz.*, to concentrate the tomatoes and to blend the tomatoes and flavoring materials.

The end point is determined by appearance, although the tomatoes are usually weighed and concentrated to a definite volume as with catsup.

Bottling.—Wide-mouthed bottles are used because of the large pieces of tomatoes present in the sauce. An automatic rotary filler is used, and the bottles are sealed with special caps in an automatic sealer. If filled boiling hot, sterilization is not necessary; otherwise the bottles are pasteurized at 180 to 200°F. as described for catsup.

HOT SAUCE

An important amount of tomatoes is used in hot sauce, a lightly spiced purée of hot flavor sold in small cans for flavoring in cooking. It can be prepared cheaply and frequently sells retail for 5 cents per 8-oz. can. Numerous formulas are in use, in which cayenne is the predominating flavoring. The following formula is typical:

To 700 gal. of raw pulp add the following ingredients finely ground:

	Pounds
Green chili peppers	100
Onions	75
Garlic	$2\frac{1}{2}$

Concentrate to about 425 gal. and add:

	Pounds
Ground cayenne pepper	$2\frac{1}{2}$
Salt	70

Stir thoroughly or boil a short time to dissolve salt and to mix the cayenne; can boiling hot and seal at once in 8-oz. cans.

In some cases the garlic is omitted and the proportions of other ingredients reduced in order to produce a sauce of milder flavor.

The tomatoes are sorted, washed, trimmed, and pulped as in making purée, paste, or catsup. The expense of hand peeling is therefore avoided.

TOMATO JUICE

Statistics.—The pack of canned and bottled tomato juice has grown from practically nothing in 1928 and 165,251 cases in 1929 to 8,170,640 cases in 1935. The 1935 pack was approximately 40,000,000 gal. of

juice, a quantity nearly as great as the annual consumption of commercially made wine in the United States. Tomato juice is used largely as a breakfast drink, although suitable for use in many other ways. Relatively little juice is bottled; most of it is canned. California, New York, Indiana, and Maryland were the heaviest producers in 1935.

It is unflavored except for the addition of a small amount, about 0.60 per cent or less, of salt.

Food Value.—Kohman (1931) states that when it is properly made and preserved it contains about as much vitamin C and vitamin B and several times as much vitamin A as orange juice. Tressler rates it considerably below orange in vitamin C content. Like orange juice it contains considerable basic ash, and on digestion leaves an alkaline residue. It is a good source of Fe, Mn, and Cu.

Definition.—The federal food and drug regulations define tomato juice as "the unconcentrated, pasteurized product consisting of the liquid with a substantial portion of the pulp, expressed from ripe tomatoes with or without the application of heat and with or without the addition of salt." This definition excludes filtered juice since it does not contain pulp.

Varieties.—Tomatoes to be used for juice should possess high color, rich flavor, high total acidity and be juicy rather than "mealy" in texture. The Stone is a very good juice variety; the Alameda Trophy, Norton, and several strains of the San Jose Canner are used in California for juice. Overripeness results in a juice of poor flavor and underripeness in one of poor color and flavor.

Preparation for Pressing.—Great care must be taken in sorting, trimming, and washing tomatoes for juice production. Many canners not only trim out unfit portions of the fruit, but also remove the core, since it may impart a harsh taste to the juice and yield chlorophyll, which turns brown on heating, imparting a dull color to the product. These operations are conducted as previously described for preparing tomatoes for purée and catsup.

Practice varies in respect to heating the tomatoes before expressing the juice. Many juice producers do not heat the fruit; others heat it for only a minute or two in live steam, sufficiently to scald the skin and flesh near the surface; and others heat the crushed tomatoes to the boiling point before expressing the juice. Pratt states that preheating is essential to securing a good product and recommends scalding for 1 to 3 min. The juice from scalded tomatoes is free of raw taste, is of better consistency and not so apt to separate into a layer of pulp and one of clear juice in the final package or in the glass.

Retaining Vitamin C.—One of the most difficult problems is to prevent loss of vitamin C through oxidation. According to data reported by Kohman (1931) practically all of this vitamin may be lost if the juice is

heavily aerated during extraction of unheated tomatoes; presumably vitamin C is oxidized by the dissolved oxygen through oxidase enzyme action. He found that heating the tomatoes to boiling before extraction prevented loss of vitamin C. He also found that it is retained if the juice after extraction is immediately subjected to a high vacuum. If vacuumizing is omitted, it would then appear that the tomatoes should be heated sufficiently to destroy the oxidase before expressing the juice, and it would also seem that a mere short scalding (1 to 3 min.) of the whole fruit would be inadequate for protection of C. One procedure calls for coarsely slicing the tomatoes, heating to boiling, out of contact with air, in a steam-jacketed conveyer and pulping scalding hot, a method that has much to commend it as a means of protecting C.

At any rate it is recommended that tomato juice canners take all reasonable precautions to retain vitamin C because the value of the product as a food depends largely on its C content. Particularly is this true if it is to be used as a food for infants. The vitamin C content of the canned product should be determined regularly during the season. This can be done quickly by the iodine-titration-vitamin C assay or by titration with standard 2,6-dichlorophenol indophenol (see Joslyn, Marsh, and Morgan).

Vitamin A.—Vitamin A resides in the solid pulp and is insoluble in the liquid portion of the juice; therefore, a reasonable proportion of the solid pulp should be included. Vitamin A is stable to heat and is not affected by the oxidation normally occurring in tomato juice production. Vitamin B also appears to be rather stable under normal conditions of tomato juice production.

Expressing the Juice.—In the early years of the industry much of the juice was prepared by passing the raw tomatoes through a cyclone (pulper), a procedure that destroys practically all of C and gives a juice of poor flavor. Special machines have been developed for the purpose and are now in general use. The most common form consists of a tapered screw revolving within a cylinder of perforated metal with holes 20/1000 in. in diameter and 625 holes per square inch. The pressure applied can be varied to attain the degree of extraction desired. It is usually recommended that not more than 60 per cent of the fruit be recovered as juice; this yield is attained with light pressure. Heavy pressure gives juice of too thick consistency and of harsh flavor.

The juice extractor and other metal equipment should be made of metal that does not affect the flavor and color of the juice; iron and copper particularly should be avoided. Pratt recommends stainless steel, monel metal, nickel, aluminum, and glass-lined steel.

Salting.—Salt may be added before canning, the amount usually being 4 to 6 lb. per 100 gal. If added at this time, it should be dissolved previously in a small amount of the juice, because when added in the dry

condition, it tends to sink without dissolving. Some canners prefer to add it as small pellets or as a small, measured volume of granular salt to the individual cans as they pass through the can-filling machine.

Homogenizing.—At one time much tomato juice was homogenized before canning, *i.e.*, it was pumped under very heavy pressure through a small orifice in order to induce a finely divided condition. Homogenizing imparts a thick consistency to the juice, and on this account if the normal amount of solid pulp is present, the juice after homogenizing is altogether too thick for use as a beverage, and if only enough pulp is left to give a homogenized juice of desirable consistency, it then is deficient in vitamin A. Homogenization unduly aerates the juice and according to Pratt injures the flavor.

Filling and Processing.—The juice is filled hot into the cans, sealed and processed at the boiling point. Plain tin is generally used although the fresh flavor is retained in greater degree in enamel-lined cans. If filled at 140 to 150°F., Pratt recommends the following process times at 212°F.; No. 1 tall cans 15 min., No. 2 cans 20 min., and No. 10 cans 30 min. If filled at 180°F., the process times are 5, 10, and 20 minutes, respectively. Cameron who recently studied the spoilage of canned tomato juice recommends filling at 170 to 180°F. and processing Nos. 1, 2, and 10 cans 15, 25, and 40 min., respectively. He found that spoilage was due to spore-bearing bacteria that accumulate in pockets in pipe lines, pumps, and other equipment during the shutdown period at night. Thorough flushing of all equipment at the end of the day and before beginning the following day's operations greatly reduces this source of infection. Spoilage is characterized by a "phenolic" or "medicinal" odor and is caused by thermophilic spore-bearing bacteria. High pH value and low acidity favor this type of spoilage; a condition prevalent in California during the 1935 season.

Use of Press Cake.—The "press cake," consisting of skins, seeds, and considerable flesh, still contains considerable juice or pulp and can be cycloned to yield an inferior pulp suitable for use in canning with standard-pack tomatoes or in making second quality catsup or other products. Catsup and other products so made are considered by-products under the food regulations.

Quality Standards for Tomato Products.—Tentative quality grades for certain tomato products were promulgated in 1932 and are discussed in *The Canner*, Oct. 1, 1932, page 17. Thus for U. S. Grade A or Fancy tomato pulp the requirements suggested were as follows:

Specific gravity	1.044 or above
Mold count	below 30 per cent
Bacteria	less than 30,000,000 per cubic centimeter
Yeasts and spores	less than 30 per 1/60 cu. mm.
Quality score	85 or above

This last (quality score) is based upon color 50, absence of defects 20, and flavor 30 for a perfect product. Color is judged by means of the Munsell system as previously described and must be better than the following minimum: 5R 2.6/13 glossy finish equal to one-third or more of total; plus 2.5 YR $5/12$ glossy finish, not over one-third of total surface; plus N 1/ glossy finish, any amount; and plus N 4/ mat finish, any amount. This is a minimum requirement for both Grades A and C. Grade A must possess good red color; be practically free of particles of seeds and must be of typical, pleasing flavor.

Grade C or Standard pulp must possess good color, be reasonably free of pieces of seeds and of reasonably good flavor. It must score not less than 70 or more than 84 as judged by color, defects, and flavor.

Substandard pulp is a wholesome edible product scoring less than 70 in quality but being within the legal limits in respect to mold count, yeast cell, and spore and bacterial count.

Similar requirements can be applied to catsup, juice, and other tomato products, particularly in respect to color, flavor and freedom from defects. It is to be hoped that standards of quality will be established and administered by proper authority for canned tomato juice, since the quality of this product on the market at present varies greatly. Particularly, a minimum requirement for vitamin C potency should be established.

THE MICROSCOPICAL EXAMINATION OF TOMATO PRODUCTS AND CHEMICAL CONTROL

If moldy, soured, or fermented tomatoes are used in the manufacture of tomato products, microscopical examination will reveal the presence of excessive numbers of the organisms responsible for the decay. B. J. Howard has made an exhaustive study of this subject, and upon the results of his investigations the U. S. Department of Agriculture has established limits for the number of molds, yeasts, and bacteria that may be permitted in tomato products.

HOWARD METHOD

This method was first published in *Bureau of Chemistry, U. S. Department of Agriculture Circular* 68 and was published a second time in 1917 in *U. S. Department of Agriculture, Bulletin* 581. It has been adopted as a tentative method by the Association of Official Agricultural Chemists. The student is referred to the latter bulletin and Cruess and Christie's "Laboratory Manual" for details of the method.

Standards for Microorganisms in Tomato Products.—The Food and Drug Administration, U. S. Department of Agriculture, and the various state boards of health consider tomato products unfit for food and subject to seizure and condemnation:

1. If mold filaments as determined by the Howard method are present in more than 50 per cent of the fields examined.

2. If yeasts and spores are present in excess of 125 per $\frac{1}{60}$ cu. mm. as determined by the Howard method.

3. If bacteria in excess of 100,000,000 per cubic centimeter as determined by the Howard method are present.

Howard recommends a limit of 25 per cent for molds, and it is perfectly feasible, by careful sorting and by the use of sound material, to produce, commercially, tomato products well below this suggested limit.

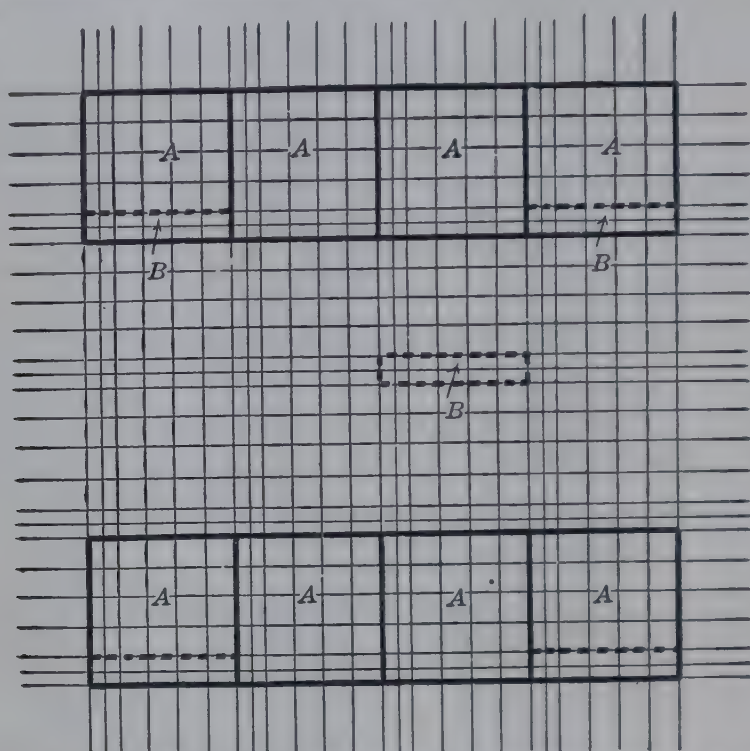

FIG. 70.—Rulings of Zeiss Haemetimeter used in the examination of tomato products.

The present standard of 50 per cent is liberal. The same will apply to the present limits for yeasts and bacteria.

Interpretation of Results.—The presence of large numbers of mold filaments indicates the use of unfit moldy raw material or contamination of the pulp by uncleanly, moldy equipment. It usually indicates the former condition and calls for more careful picking in the fields and more rigid sorting and trimming.

The presence of an excessive number of yeasts, spores, and bacteria usually indicates fermentation during a delay in the process of manufacture, although if the fruit is stored too long before pulping, fermentation and growth of these microorganisms may occur in cracked or crushed tomatoes before pulping.

Since the mold count is so much more important than the estimation of spores, yeasts, and bacteria, it is the determination most frequently made by pure food officials and prospective purchasers of large quantities of tomato products,

Relation of Percentage of Rot to Mold Count.—It has been determined by Howard that there is a fairly definite relation between the percentage of rot by weight and the mold count. Numerous determinations were made of the percentage of rot in 25- and 60-lb. samples of the tomatoes from the sorting and trimming belts in a number of factories and of the per cent of fields of the finished pulp-containing mold. The results of these determinations are shown graphically in Fig. 71.

None of the samples containing less than 1 per cent by weight of rot gave excessively high mold counts. While the results show that a low

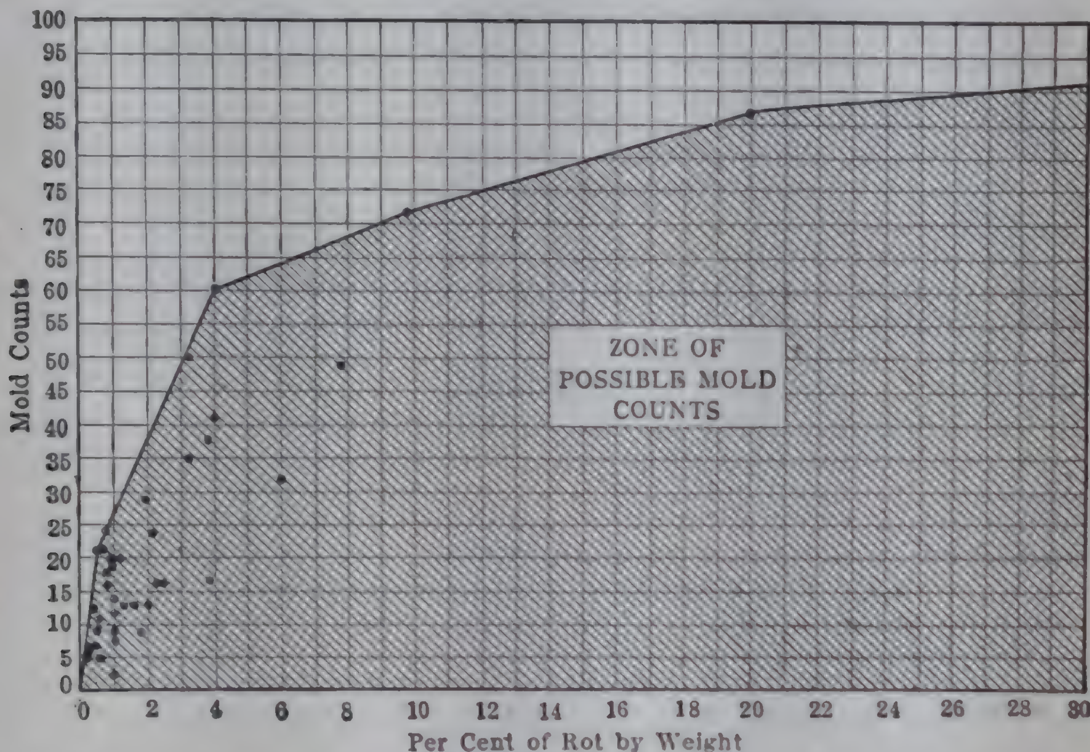

FIG. 71.—Relation between percentage of rot in fresh tomatoes and mold count in pulp. (*After Howard.*)

count may not always indicate the use of sound raw material, they clearly demonstrate that a high mold count always indicates the use of unfit material (provided the molds have not come from unclean equipment). Any weakness in this method of determining the quality of the product favors the manufacturer and may occasionally permit products which should be condemned to pass inspection.

In the figure, percentage of rot above 20 per cent are plotted as if 100 per cent would give a count of 100 per cent of fields showing mold. As a matter of fact, a count of 100 per cent will often be obtained with pulp made from tomatoes containing less than 20 per cent of rot by weight.

From the chart it is possible to estimate the minimum per cent by weight of rot in the raw material. Thus a mold count of 40 enters the "Zone of Possible Mold Counts" at a point representing 2.2 per cent of rot by weight. A count of 40, therefore, may represent from 2.2 to 100 per cent by weight of rot in the raw material but not less than 2.2 per cent.

Relation of Per Cent of Rot to Bacteria, Yeast, and Spore Counts.—Counts of less than 15,000,000 bacteria per cubic centimeter indicate little as regards per cent of rot in the original material, but above this point, according to Howard, each per cent increase in weight of rot gives an increase of about 20,000,000 bacteria per cubic centimeter. This relation holds to about 20 per cent by weight of rot. A low bacterial count does not always indicate the use of sound material.

The same general relations exist for yeasts and spores as for bacteria.

Effect of Peeling on Counts of Microorganisms.—Chili sauce and canned tomatoes are prepared from peeled and well-trimmed stock in most cases, and as a consequence extremely low counts of molds, yeasts, and bacteria are the rule for such products. Similarly, coring the unpeeled tomatoes used for pulp, catsup, juice, etc., greatly reduces the mold count. This is common practice in California at present, the primary purpose being to remove corn-ear worms and other larvae.

Effect of Method of Storage of Pulp.—In former years it was customary to store tomato pulp (to be used for catsup, etc.) in wooden barrels with distilled vinegar or sodium benzoate as a preservative. Almost invariably such pulp has shown on microscopical examination after several months' storage very high counts of bacteria and often high mold counts.

Because of the frequent condemnation by the food officials of barrel stock, this method of storage has practically gone out of existence and has been replaced by sterilization in 5-gal. or No. 10 cans.

Effect of Concentration.—In highly concentrated tomato products, such as tomato paste, the increase in numbers of mold filaments is not strictly proportional to the degree of concentration. Thus if tomato pulp is concentrated 5:1, the molds will not increase in a similar ratio but will show a considerably smaller increase, probably because of breaking up of the filaments and shriveling of the mold filaments by osmosis to such an extent that they are no longer recognizable under the microscope as molds.

This condition exists to a more limited extent with other concentrated tomato products, such as catsup, highly concentrated purée, etc., although it is most pronounced in tomato paste.

For this reason food officials have experienced difficulty in establishing standards for tomato paste.

Accuracy of the Howard Method.—Some food chemists and manufacturers of tomato products are inclined to doubt the value of the Howard method as a means of detecting spoilage or the use of unfit raw material. It has been proved many times, however, that the method in the hands of experienced analysts gives strictly comparable results and that it is possible to obtain results upon the same sample that agree

closely. It has also been shown that any error in the method is more liable to favor the manufacturer than the food official. Its principal weakness lies in the fact that it does not always give a high count with products known to have been prepared from tomatoes containing an excessive amount of rot.

Howard Method for "Worm Count."—In 1934 and 1935 infestation of tomatoes with the corn-ear worm and to a lesser degree with the larvae of the potato-tuber moth was heavy in certain Western states. Dr. B. J. Howard of the Federal Food and Drug Administration made an investigation in canneries and in the fields of the extent and character of the infestation and the methods of handling the tomatoes to remove the insects. He devised a method of detecting the worm fragments in the finished product.

Tomato fruits become infested by young worms hatching from eggs laid on the plant by adult females. The young worms feed to a slight extent on the leaves, but usually crawl under the calyx of a tomato and burrow downward into the core. They carry on their feeding operations there and increase rapidly in size as well as in destructive action. The worm may develop to maturity in the core of the tomato or may move about from one tomato to another, cutting small feeding holes around the calyx, or on the sides of the fruit. Microorganisms often gain entrance through the worm holes and cause decay. A tomato in which the worm develops to maturity becomes a mass of worm excreta, disgusting in appearance, and wholly unfit for use in a food product.

It is difficult to control the worms by use of arsenicals or other poisonous sprays because of contaminating the fruit with the poison, making its use in the fresh state or unpeeled condition for tomato products dangerous. However, the problem of control in the fields is receiving intensive study. Much can be done by pickers to discard evidently infested fruit in the fields. Experiments with dusting with powdered calcium arsenate are being made and appear hopeful; it can be removed from the fruit at the plant by proper washing.

Often the presence of the worm in the core is not evident from the outside appearance of the fruit, and on this account many canners now core all the tomatoes used for juice, puree, and other products. Incidentally, coring greatly reduces the mold count since mold is frequently found in the stem cavity.

Howard has adapted to the estimation of worm fragments in tomato products the method of J. D. Wildman, developed for recovery of small insects from certain other food products. The method in brief is as follows (quoting from Howard):

A one hole, rubber stopper, which is of such size that it will just pass snugly down the neck of a 2 liter Erlenmeyer flask, is pushed down to the bottom of such

a flask by means of a small supporting rod fitted through the hole in the stopper. Two hundred cubic centimeters of the product to be tested (100 grams in the case of paste, mixed with 200 cc. of water) is placed in the Erlenmeyer flask, 20 cc. of gasoline is added and the mixture shaken. Then water at room temperature is added in such fashion as to vigorously agitate and mix the whole combination thoroughly until the flask is filled up into the constricted neck. The flask is allowed to stand for a few minutes, during which time the contents are very gently rotated by means of the rod and the stopper. In this manner the insect fragments are brought to the top with the gasoline. The gasoline layer and a shallow portion of the aqueous layer are then entrapped in the neck of the flask by raising the rubber stopper until it fits snugly in the lower end of the flask neck. The entrapped portion above the stopper is poured out into a quick action filter paper in a suction Buchner funnel. After the liquid portion has been drawn through, the residue retained on the filter paper is examined under a low power, wide angle, binocular type microscope giving magnifications of about 10 and 20 fold. The fragments of insects are located and identified and their number noted. As a foundation for this determination the analyst should familiarize himself with the appearance of the characteristic structures of the insects through examination of larvae of known authenticity.

By means of this method there have been recovered from some commercial samples a maximum of over 100 larvae fragments per 200 c.c. of product. The fragments most commonly encountered are those of the skin, quite easily distinguished by the characteristic structures on them such as seta (hairs) and small spine like processes. Not infrequently, various mouth and skull fragments are found as well as the true and false feet in whole or in fragments. Spiracle openings, the breathing pores located along the sides of the insect, are also not infrequently encountered.

The present tolerance established by the Federal Food and Drug Administration is a maximum of 20 fragments per 200 cc. of such products as purée and catsup and 10 per 200 cc. for juice. These are tentative standards and will probably be revised as more data are accumulated.

In making the microscopical examination usually the filter paper containing the sample is covered with a coarse mesh made of silk thread or fine metal wire which divides the field into small squares, each about ¼ in. in diameter. These greatly facilitate counting. A strong light focused on the field is essential to effective examination. A dissecting needle or merely a sewing needle mounted on the end of a slender rod is very useful in turning over fragments of pulp to facilitate microscopical examination. Fragments of certain spices may be mistaken for worm skin fragments. As suggested by Howard the analyst should thoroughly familiarize himself with the microscopical appearance of worm fragments prepared by grinding larvae of the corn-ear worm and other larvae involved (such as potato-tuber moth larvae and pinworms). In addition, he should receive personal instruction from a state, federal, or other microscopist engaged in this work.

LABORATORY CONTROL

Value of Microorganism Counts.—The foregoing considerations have shown the importance to the manufacturer of knowing at all times that his product conforms to the standards established by law for tomato products. For this reason, if for no other, a laboratory should be maintained for the inspection of every batch of tomato pulp or other tomato product.

Manufacturers of large quantities of pulp and catsup are finding it increasingly essential to know very definitely that their product is below the legal tolerance in content of worm and insect fragments.

Analyses of the pulp and finished products at the time of manufacture enable the plant superintendent to detect careless sorting and trimming at once or the arrival at the plant of tomatoes that carry excessive numbers of microorganisms.

Specific Gravity and Refractive Index.—In addition to examining tomato products microscopically the chemist is of very great value to the tomato products factory in controlling the specific gravity of the pulp, etc. The average cannery workman cannot be trained to make reliable determinations of specific gravity or refractive index. Boiling the pulp to a definite volume, or use of some other more or less hit-or-miss method of determining the finishing point for pulp without laboratory control, leads to heavy losses in one of two ways. Either the product is liable to be frequently below the gravity demanded by the purchaser and a damage suit, rejection, or price penalty ensues, or the product is too highly concentrated and a low yield is thereby obtained, with consequent loss to the manufacturer and gain to the purchaser.

The magnitude of such loss may be indicated by the following consideration. If the manufacturer desires to produce purée of a specific gravity of 1.035 to fill a contract and, having no chemist, concentrates the purée to an average of 1.04 he will find that his yield will be reduced in the ratio of 100 to 114.7, *i.e.*, 114.7 gal. of pulp of 1.035 is equal to only 100 gal. of 1.04 specific gravity. On an output of 10,000 gal. of pulp per day this corresponds to a daily loss of 1,470 gal. In addition to the direct value of the chemist, there is the indirect increase in value of the product due to improved quality.

Research.—The time of the chemist can be utilized to advantage during the dull season of the year in investigations of the utilization of by-products, in devising new products that will prolong the operating season of the plant, and in studying other problems of importance to the plant.

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CHAPTER XX

SUN DRYING OF FRUITS

The preservation of foods by drying is one of the oldest and most important of the food industries and considerably more fruit is preserved by drying than by any other means.

Until relatively recently, Asia Minor, Greece, Spain, and other Mediterranean countries produced most of the world's supply of sun-dried fruits; but California has now become the most important producer of raisins, dried peaches, prunes, and apricots. Although the date industry in that state is becoming important, the total production is relatively small compared to that of North Africa and Asia Minor.

New York and the Pacific coast states produce the bulk of the dried apples in the United States, but this fruit is dried by artificial heat and not in the sun.

Extent of Industry in California.—Except in California almost no fruit is sun dried in the United States. The extent of the industry is indicated by the data in Table 56.

TABLE 56.—PRODUCTION OF SUN-DRIED FRUITS IN CALIFORNIA

Fruit	1903–1907 average, tons	1917, tons	1919, tons	1921, tons	1935, tons
Apricots	8,200	15,000	14,500	6,500	25,800
Figs	3,000	2,000	11,000	6,500	24,000
Peaches	14,500	5,000	35,000	22,000	19,500
Prunes	67,500	115,000	135,000	112,500	258,000
Raisins	54,000	163,000	187,575	122,500	203,000
Pears	No data	No data	No data	2,500	5,000
Dates	No data	No data	No data	1,000	3,250
Total	147,200	300,000	383,075	273,500	538,550

Advantages of Dried Foods.—Dried foods are in more concentrated form than foods preserved in other ways. They are less costly to produce than canned or preserved food, because of lower labor costs and the fact that no sugar is required.

Dried fruit requires less storage space and a smaller number of cartons or boxes than an equivalent amount of fruit in canned or preserved form.

A ton of apricots after canning weighs approximately 2,800 lb., if the

weight of cans and boxes is included. A ton of fresh apricots yields about 400 lb. of dry fruit, which when packed will weigh not more than 450 lb., or less than one-sixth as much as the equivalent amount of canned fruit.

With vegetables the difference in weight of the dried and canned articles is even more striking.

It can readily be seen that the cost of transportation will be very much less for dried than for canned or fresh fruits and vegetables.

For these various reasons dried fruits are usually considerably less costly to the consumer than the equivalent quantities of canned or preserved fruits.

EQUIPMENT FOR SUN DRYING

The equipment used for the drying of fruit varies considerably with the variety of fruit to be dried and with local conditions, but there are certain pieces of equipment that are common to several varieties of fruit.

The Dry Yard.—Fruits are transported from the orchard to a centrally located yard to be dried, generally, but the grape is usually dried in the vineyard between the rows of vines.

The term "dry yard" is usually taken to include both the area used for the trays of drying fruit and the buildings and equipment that are used in preparing and storing the fruit.

The area required for the dry yard varies with the variety of fruit to be dried, the yield per acre, and local weather conditions. Less area is required in a region where the temperature is high and the humidity is low than is required in a region of cool days and foggy nights. Under California conditions the ratio of the dry-yard area to bearing orchard or vineyard area is: for prunes, from 1:10 to 1:40, with an average of about 1:20; for apricots, from 1:10 to 1:25, with an average of about 1:22; and for pears, about the same ratio as apricots except in localities where most of the drying is done under sheds, where the area required is less than for apricots. Peaches require about the same drying area as apricots and pears and figs require less space than apricots. Dates are usually allowed to dry on the trees, or are dehydrated.

The dry yard should be protected from dusty roads, and the driveways in the yard should be sprinkled frequently or oiled to prevent the accumulation of dust on the drying fruit. The yard should not be near stables or other breeding places for flies. Bees and wasps become a serious pest during the late summer and early fall months if the hives are near the yard. In very windy sections the yard should be protected by a windbreak.

The yard should be so designed with reference to the dipping and cutting sheds that the fruit can be handled efficiently, and it should be near

the orchard. Figure 72 illustrates a suitable dry-yard layout as designed by A. W. Christie and L. C. Barnard of the University of California.

Cutting and Dipping Shed.—The fruit cutters and other workmen engaged in the preparation and traying of the fruit should be protected from the sun. An open shed, equipped in large yards with car tracks, cutting tables, and dipping equipment, is usually built for this purpose. The shed should be so designed and equipped that the fruit may be

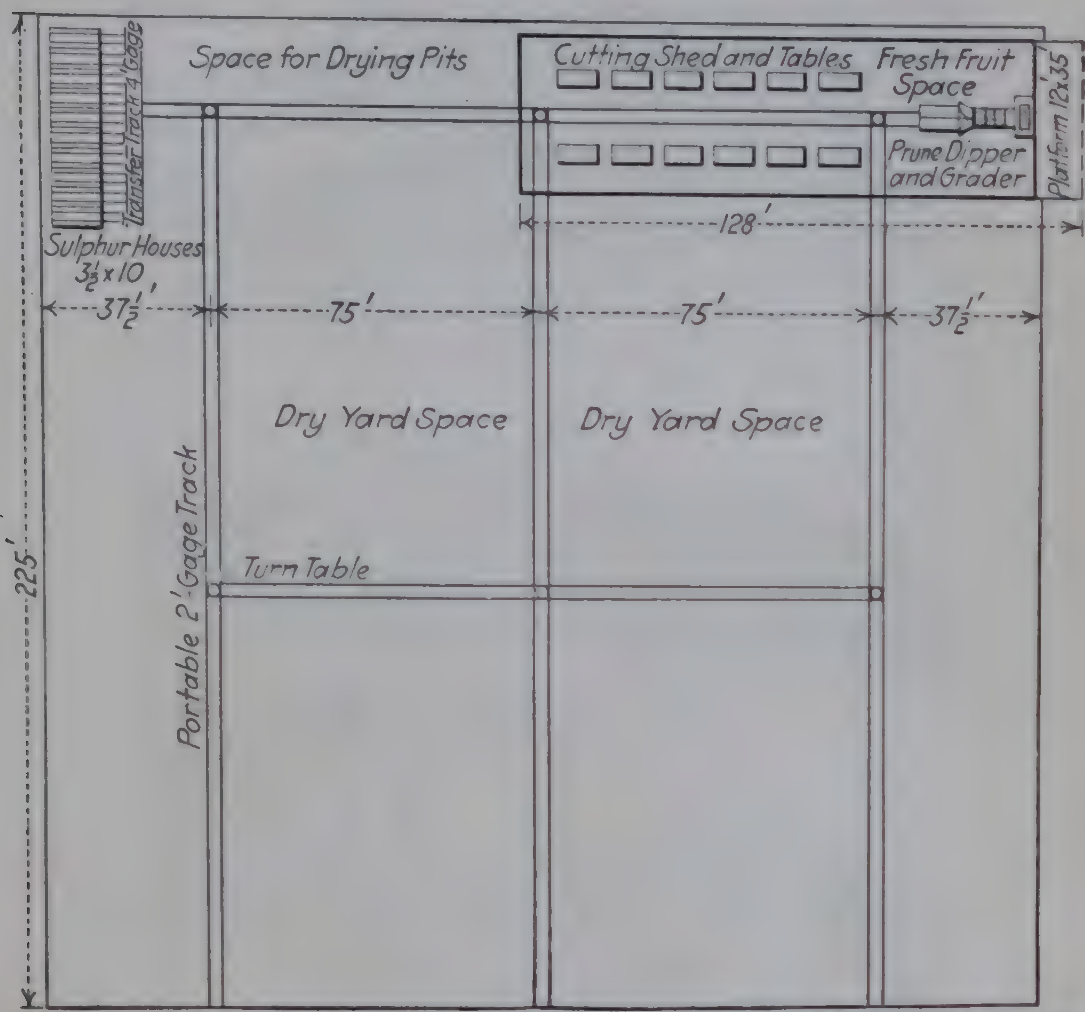

FIG. 72.—Ground plan of a fruit drying yard of approximately 2½ acres. (*After Christie and Barnard.*)

carried through it during cutting, dipping, etc., in the most efficient and direct manner possible and with the minimum of confusion.

Sulfuring Equipment.—Pears, peaches, and apricots are exposed to the fumes of burning sulfur before the fruit is placed in the dry yard. The usual sulfur house for peaches and apricots consists of a wooden, brick or concrete chamber a few inches longer and wider than the trays and high enough to accommodate a dry-yard car loaded with 20 to 25 trays. The fruit is sulfured by burning sulfur in a small pit in the floor of the sulfur house for the required length of time, for most fruits 3 to 6 hr.

Figure 74 illustrates the appearance of typical sulfur houses.

A cheap and convenient form of sulfuring device is the "balloon hood," which consists of a light wooden frame covered with heavy roofing or building paper or canvas made airtight with tar paint. This light chamber can be placed over a stack of trays in the dry yard, making the use of cars unnecessary. It is not very durable and is probably less convenient than the standard sulfur house.

FIG. 73.—Upper: Typical cutting shed for pears and apricots. Center: Large concrete cutting shed for apricots. Lower: Hauling apricots to the drying yard.

Brick or concrete sulfur houses are permanent and more nearly fume-tight than wooden structures. It is desirable to equip the sulfur box with an adjustable opening in the roof to provide proper ventilation for continuous burning of the sulfur and distribution of the fumes. Success in sulfuring requires a fume-tight structure with adjustable air inlets and outlets. Trays must be so stacked that the fumes may reach all the fruit readily. The sulfur must be fresh and free of oil.

Placing the sulfur burning pit at the rear of the sulfur box is desirable because the fumes from the pit then do not annoy the workmen so much

during placing of the trays in the box and during removal of the car of trays after sulfuring. A small door is cut in the rear wall of the sulfur box to permit lighting of the sulfur in the pit.

Transfer Systems.—The trays are usually transported in the yard by means of small cars on light steel rails. The cars are low and fitted with wooden frames of the size of the trays and are moved by hand (see Fig. 74).

Turntables or transfer cars and tracks are used for transferring the cars at right angles to the main track.

The track system should be carefully planned in order that all portions of the dry yard may be conveniently reached and so that loaded cars may be transferred to the yard and empty cars from the yard to the preparation shed without confusion. The track system shown in Fig. 72 is satisfactory.

In some yards the trays are hauled on low-wheeled wagons by motor power or by horses. This method of transfer is more flexible than the track and car system but probably more costly in operation.

Trays.—The tray universally used in California is made of pine or redwood shakes on a light wooden frame.

The sizes in most common use are as follows: 2 by 3 ft. with ends or sides open, used for grapes and figs; 3 by 3 ft. with ends open, used for prunes and grapes; 3 by 6 ft., ends and sides usually closed, used for prunes, pears, grapes, apricots, and peaches; 3 by 8 ft., ends and sides closed, used principally for prunes but also for apricots, peaches, and pears.

The lists of materials for the 3- by 8-ft. and 2- by 3-ft. trays are as follows:

3- BY 8-FT. TRAY

2 pieces, 1″ × 2″ × 8′
2 pieces, 1″ × 2″ × 2′ 10″
15 pine shakes, 6″ × 3′
3 pieces, 1½″ × ⅜″ × 8′

2- BY 3-FT. TRAY

2 pieces, 1″ × 1½″ × 3′
6 pine shakes, 6″ × 3′
2 pieces, ⅜″ × ⅞″ × 3′

The appearance of the various trays is shown in Figs. 75, 77, and 78.

Cutting Tables.—Peaches, pears, and apricots are cut in half and pitted or cored before being placed on the drying trays, which rest on a table in front of the cutters. In its simplest form the cutting table consists of two sawhorses or several lug boxes upon which the tray rests.

A well-built table is more rigid and convenient than the sawhorse or lug-box supports. A convenient cutting table devised by L. C. Barnard, of the University of California, consists of a frame 3 ft. in width and 8 ft. long. This will accommodate four 2- by 3-ft. trays three 3- by 3-ft. trays or one 3- by 6-ft. or 3- by 8-ft tray. The top of the frame is at a convenient height for the cutters, about 33 in. from the ground. At

the sides of the table are supports for lug boxes, from which the fruit can be readily taken to be cut and spread on the trays.

The cutting tables are movable and are placed in the cutting shed in such position that the fruit and trays may be carried to and from the tables conveniently.

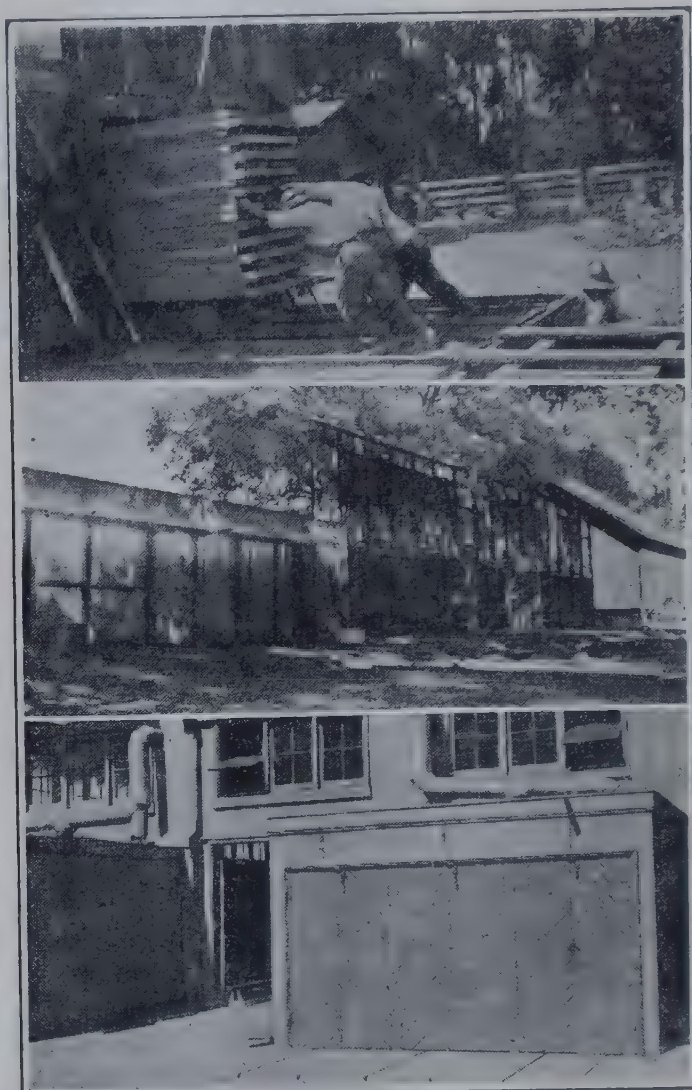

FIG. 74.—Houses for sulfuring cut fruit. Note method of staggering trays in upper picture to facilitate contact of sulfur fumes with fruits.

Boxes.—The fresh fruit is usually transported to the dry yard in lug boxes holding 40 to 60 lb. of fruit.

The dried fruit is either stored in bins or is placed in sweatboxes, which are pine boxes about 10 in. deep and 3 by 4 ft. in size. Sweatboxes are more generally used for raisins than for other dried fruits.

Storage Space for Dried Fruit.—Dried fruit must be protected from insects during storage. A room, therefore, should be provided which is insectproof and which may be fumigated with carbon bisulfide or other gas or vapor. See also fumigation section in Chap. XXII.

The store room is equipped with bins, usually rectangular and 4 to 8 ft. deep, in which different lots of fruit may be stored separately.

The front wall of each bin is made of removable boards to facilitate filling and unloading. In some cases the dried fruit is placed in heaps on the storeroom floor and bins are dispensed with.

"Sweating" of the fruit, *i.e.*, equalization of the moisture in the fruit and softening of the skins by moisture from the interior of the fruit, is considered an essential step in the process of drying and curing. The bins facilitate the sweating process.

Other equipment will be discussed under drying of the various fruits.

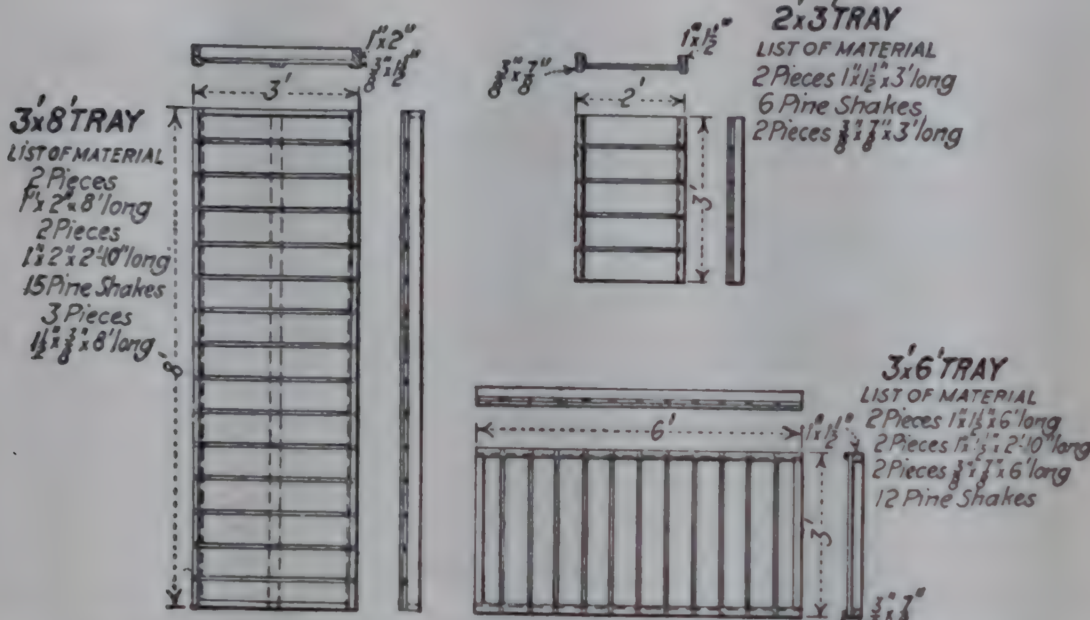

Fig. 75.—Sketches of various sun-drying trays with lists of materials. (*Sketch by Barnard.*)

Lye Dipping.—Prunes, and in some sections grapes, are dipped in a dilute solution of sodium hydroxide, sodium carbonate, or other alkaline solution for the purpose of removing the wax coating and checking or slightly cracking the skins of the fruit in order to increase the rate of drying.

The simplest form of lye-dipping apparatus consists of a heavy cast-iron kettle filled with dilute lye solution and mounted over an oil-burning furnace. The fruit is dipped in the kettle of boiling lye solution by means of a small woven-wire basket holding 25 to 50 lb. of fruit.

A very common form of dipping outfit used by small dry yards consists of a brick furnace about 6 ft. high in which is set a rectangular sheet-metal tank containing the lye solution. At one side of the dipping outfit is an unloading platform on which the lug boxes of fresh fruit are placed and on which the workman who operates the dipping outfit stands (see Fig. 76). A rectangular basket with rounded bottom holds the fruit during dipping and is operated by a hand lever. A second tank and a second basket may be placed beyond the first basket for rinsing the lye-dipped fruit. Prunes are usually not rinsed, whereas grapes are generally

thoroughly rinsed to remove all adhering lye solution. The lye tank is generally heated by an oil burner.

Continuous dipping machines similar to that shown in Fig. 76 are used in some large dry yards. The spray type of lye peach-peeling machine has proved very satisfactory for dipping prunes and grapes for drying.

Sodium hydroxide is generally used in preference to other alkaline substances in the dipping solution, although sodium carbonate and mixtures of sodium carbonate and sodium hydroxide are used to a limited

FIG. 76.—Lye-dipping equipment for prunes and grapes. Upper: Dipping prunes. Lower left: Continuous grape dipper. Right: Hand-power prune dipper.

extent. Sodium bicarbonate is sometimes used for the dipping of Sultana grapes, but its action is not severe enough for prunes or tough-skinned grapes.

The concentration of the lye-dipping solution varies according to the variety of fruit, its maturity, and the district in which the fruit is grown. The maturity of the fruit also affects the strength of the solution necessary to check the skins satisfactorily. Green fruit requires a more concentrated solution than ripe fruit of the same variety. Prunes grown in the hot interior valley of California require stronger solutions for dipping than those grown in the coast countries.

PRUNES

In the past almost the entire prune crop in California has been dried in the sun. In 1918 the industry suffered a loss of approximately $5,000,000 because of early fall rains which caused the spoiling of the fruit on the trays. Since that date, interest in the use of dehydraters has

increased and at present a considerable and increasing proportion of the crop is being dried by artificially produced heat.

Varieties.—The French prune (*Petite Prune d'Agen*) is the principal variety grown in California. The trees of this variety produce regularly and heavily, but the fruit is smaller than that of most other varieties grown commercially in California.

The Sugar prune, the second in importance in California, is larger than the French prune and ripens several weeks earlier than the latter. The skin of the Sugar prune is more tender than that of the French prune

FIG. 77.—Upper: Soaking and washing prune drying trays. Lower: Transfer car and tracks to sulfur houses. Right: Prune drying trays.

and therefore more easily checked in lye dipping. It molds and ferments more readily than the French variety and for this reason requires more care during drying, and it does not bear so heavily as the French prune.

The Imperial prune is a very large variety, but the tree does not bear so regularly or so heavily as the French variety. It is a very difficult fruit to dry successfully in the sun, because of fermentation and darkening of the flesh near the pit but, when properly dried, commands a premium because of its large size. It can be dehydrated easily, a fact which should eliminate the principal objection to it.

The Robe de Sargent is a variety grown in limited quantities only. It is less desirable than the French prune, since it is no larger than the latter and usually contains less sugar.

Several selected and new strains of the French prune are being advocated at the present time by nurserymen. The most promising of these new strains is probably the Coates "1418" prune.

The Silver Plum is sulfured and dried in the sun to a limited extent.

The Italian prune is not grown commercially in California for sun drying, although it is the principal variety grown in the northwest for dehydrating purposes.

Harvesting.—In California, prunes are allowed to ripen on the tree and to fall to the ground of their own accord. They are then picked from the ground by hand into lug boxes. At the end of the season fruit which has not ripened sufficiently to fall of its own accord is shaken or knocked from the trees, but this fruit is not so sweet or of so good a color as that which ripens and falls naturally.

The fruit should not be allowed to lie on the ground too long, because it is liable to mold or become partially dried and difficult to check by lye dipping.

The orchard soil should be rolled at the beginning of the season in order that the fruit will be injured as little as possible and that picking may be facilitated.

Usually four to five pickings are made during the season.

Dipping and Size Grading.—At the dry yard the prunes are dumped from the lug boxes into the dipping machine. For French prunes the lye solution varies from 0.25 to 1.5 per cent according to the maturity of the fruit and the locality. In the Sacramento Valley the [illegible] solution is used and in the Santa Clara Valley and other coastal regions solutions of approximately 0.5 per cent are generally employed. The above percentages correspond to about 4 to 12 lb. of lye per 100 gal. of water. For dehydration, prunes are often dipped in boiling water.

Length of Dipping.—The prunes remain in the lye solution from 5 to 30 sec., the average time being approximately 15 sec. The rotary automatic dipper is used in the large yards and the hand-power basket dipper in the small yards.

Sugar prunes require a weaker lye solution than French prunes and a shorter period of dipping. The Imperial prune is more tender than either the French or Sugar varieties and is dipped in a very dilute solution (0.25 per cent) or in boiling water only. Some growers place Imperial prunes undipped on the trays in the sun for several days before dipping, in order to shrivel and toughen the skins slightly.

Needle Board.—At one time most prunes were passed over a needle board after dipping, in order to puncture the skins. This practice has now been discarded in most yards.

Size Grading.—Prunes should be graded for size after dipping, in order to promote uniformity of drying, because much of the small fruit is partially dried before it arrives at the yard and becomes over-dried if mixed with the larger fruit. In most yards two or three grades only are

made. In some yards the slabs or culls are separated from the remainder of the fruit by hand and dried on separate trays.

Appearance of Dipped Fruit.—A properly dipped prune should exhibit very small cracks over its entire surface; the skins should not be partially peeled from the fruit nor should any great proportion of the fruit pass through the dipper without checking of the skins. If the solution is too weak, the prunes must be submerged in the lye for such a long period that many of them become partially cooked and some burst or are partially peeled. If the lye solution is too strong, the fruit is apt to be partially peeled or the cracks in the skin too large. It is desirable that the solution be maintained actively at the boiling point for the best results.

Renewing the Solution.—In most yards the lye solution is replenished from time to time during the day by the addition of fresh lye in granular form and by adding water to replace that lost by evaporation, neutralization, and adhering to the fruit. It becomes necessary to remove the lye solution occasionally and replace it with freshly prepared solution because of the accumulation of sugar, dust, and salts of sodium.

Rinsing.—Prunes are generally not rinsed after dipping, although rinsing improves their appearance.

Traying.—The dipped prunes fall from the grader or dipper to trays placed in the proper position to receive the fruit (see Fig. 76).

The tray most commonly used is 3 by 8 ft. in size, and when the prunes are placed on the tray, one layer deep holds approximately 75 to 90 lb. of fruit. The fruit is spread by hand.

The loaded trays are stacked on a waiting dry-yard truck, usually about 20 trays per truck, and taken to the dry yard.

Spreading and Drying in Sun.—The trays are spread in rows on the ground as shown in Fig. 78 with pathways between the rows to permit handling of the fruit and tray during drying.

Sugar and Imperial varieties usually require stirring to prevent molding, after the fruit has been on the trays for 3 or 4 days.

Stacking.—After the prunes have become two-thirds to three-fourths dry, the trays are stacked one above the other in such manner that the air may pass freely between the trays, and drying is allowed to continue in the stack. If dried completely in the sun, much of the fruit is apt to be overdried.

In good drying weather the trays may be stacked within 4 or 5 days after dipping.

Removal from the Trays.—The fruit is dried to a moisture content of approximately 12 to 18 per cent. The grower determines the end point by the feel of the fruit. The pit in a properly dried prune should not

slip between the fingers when the prune is pressed, and the texture should be leathery and the flesh firm. The prunes should not be so dry that they rattle on the trays. Overdried fruit results in low yields, while underdried fruit will spoil in the storage bins.

The fruit is carefully sorted before it is removed from the trays in order to remove "bloaters" (insufficiently dried immature fruit), slabs (broken or overripe fruit), and split or otherwise damaged fruit.

The remaining fruit is then scraped from the trays into lug boxes and transported to the storage bins.

Sweating.—The dried fruit is placed in bins built for the purpose or is heaped in piles on a clean floor to undergo sweating, or equalization of the moisture. The overdried fruit absorbs moisture from the fruit of higher moisture content, and the surface of the fruit becomes moist through the diffusion of moisture from the interior of the fruit to the surface.

Sweating usually lasts 2 weeks or longer. In some yards sweating is dispensed with and the fruit is taken directly to the packing house from the dry yard in lug boxes or sacks.

Delivering to Packing House.—The sweated fruit is usually placed in bags for transportation to the packing house, where the fruit is weighed and samples are taken for the door test, which consists in noting quality and counting the number of prunes per pound. The grower is paid upon this basis. Further information concerning size grades will be found in Chap. XXII.

Yields.—In California the normal drying ratio for French prunes is about 2.4:1, that is 2.4 lb. of fresh fruit is required to produce 1 lb. of dry. Yields as high as 1.8:1 and as low as 3:1 are obtained, depending upon the maturity of the fruit.

The average yield of dry fruit per acre of bearing orchard is about 2 tons.

Labor Costs for Prunes.—According to data collected by A. W. Christie and L. C. Barnard of the College of Agriculture of the University of California, the average labor cost for drying prunes is approximately $3.43 per green ton.

Silver Plums.—Silver plums, or Silver "prunes," a large white variety of plum, is dried in California to a limited extent. The plums are lye dipped, as described above for other varieties of prunes, are placed in the fumes of burning sulfur for at least 4 hr., and are then placed in the sun to dry. The drying operations are similar to those for other prunes. The dried product is of amber color and of acid flavor.

Rain Damage.—In years of early fall rains, loss from rain may be serious. In such a contingency the trays should be stacked before rain begins and covered to prevent wetting of the fruit. If the rain is not prolonged, the trays may be spread in the sun later and drying completed.

If the rain is prolonged for several days, it will be necessary to complete the drying process in a dehydrater or to expose the prunes on the trays to fumes of burning sulfur for 30 to 40 min. to prevent molding and fermentation.

SUN DRYING MUSCAT GRAPES

The drying of raisins is the most important fruit drying industry. California, Australia, Greece, Asia Minor, and Spain produce most of the raisins of the world. Greece is noted for its dried currants, a small raisin made from currant grapes (not currants in the ordinary sense of the word). Spain produces principally Muscat, also known as Malaga, raisins, and several varieties of seedless raisins are dried in Asia Minor. Smyrna is one of the most important ports for the shipment of raisins from Asia Minor.

Cooperative Association in California.—The raisin growers of California in 1912 organized a cooperative marketing organization to market the 70,000 tons of raisins produced in the state at that time, which were then selling at a loss. An advertising campaign resulted in selling all of the surplus and in placing the raisin growing industry on a paying basis. Since that year the planting of vines has increased rapidly until at the present time California is producing approximately 200,000 tons of raisins annually.

The following table gives the plantings and production from 1916 to 1935 inclusive:

TABLE 57.—PLANTING OF RAISIN GRAPES IN CALIFORNIA AND PRODUCTION OF RAISINS SINCE 1916

(After Sun-Maid Raisin Growers' Statistical Department, and Giannini Foundation)

Year	1916	1917	1918	1919	1920	1921	1922*	1935
Acreage	162,381	164,547	201,991	256,452	292,938	360,076	400,375	245,000
Tons	132,000	163,000	167,000	182,500	173,500	150,900	234,800	203,000

* Tonnage for 1922 is estimated.

The association had a membership at one time of about 7,000 growers. The growers harvest and dry the grapes and may also sort out cluster raisins before delivery. The raisins are then delivered by the growers to the association's packing plants or receiving stations. Payment to the extent of not more than 50 per cent of the value of the raisins is made the growers by the association within 6 days after delivery. Final payment is made after the fruit has been sold, or at intervals during the year after receipt of the raisins at the packing houses.

The association makes with the growers a contract for a period of several years which has been proved in court to be binding on both

parties. This contract gives stability to the organization and is, undoubtedly, one of its more important features. At present the membership is less than formerly.

Relation of Maturity to Yield and Quality.—It is customary to begin harvesting the Muscat grape for drying in California at about 21° Balling, *i.e.*, when the juice expressed from the grapes tests 21° by the Balling hydrometer. Bioletti has made a thorough study of the effect of maturity on yield and has obtained rather startling results. His experiments have been confirmed by F. K. Howard and others. The following table illustrates the results obtained:

TABLE 58.—EFFECT OF MATURITY ON THE YIELD AND RETURNS FROM MUSCAT GRAPES
(*After Bioletti*)

Balling of juice at time of picking	Pounds of raisins per acre	Gross returns per acre	Cost per acre	Net profit per acre	Increase in profit per acre per cent
18	1,786	$ 89.30	$47.90	$41.40	0.00
19	1,893	94.65	48.70	45.95	8.57
20	2,000	100.00	49.50	50.50	21.98
21	2,107	105.35	50.19	55.16	33.24
22	2,214	110.70	50.88	59.82	44.49
23	2,321	116.05	51.57	64.48	55.75
24	2,428	121.40	52.26	69.14	67.00
25	2,535	126.75	52.95	73.80	78.26
26	2,642	132.10	53.64	78.46	89.52
27	2,749	137.45	54.33	83.12	100.77
28	2,856	142.80	55.02	87.78	112.03

From these results it can readily be seen that it is extremely important that grapes for drying should be fully matured. The principal reason that grapes are picked before they have reached their maximum sugar content is that, because of labor shortage, it is often difficult to pick all the grapes before there is loss from early fall rains. Many growers are now, however, insuring against rain damage by erecting dehydraters to be used during seasons of early rains. Where this provision is made, it is possible to delay harvesting until the grapes have attained at least 24 to 25° Balling. Grapes harvested immature yield, not only a smaller total amount of dried product, but also raisins of smaller size and of poorer texture and color.

Preparing Vineyard for Drying.—The rows of vines usually lie in an easterly and westerly direction, in order that the trays may not be shaded

during the morning and afternoon. A furrow is plowed on the north side of the row, in order that the trays may be tilted toward the south and thus receive the full rays of the sun. The forming of this furrow is known as "V-ing."

Harvesting.—After the furrow has been made and the grapes have attained the desired maturity, the trays, 2 by 3 ft. in size, are taken to the vineyard and distributed to the different rows. The grapes are picked directly onto the trays which are placed between the vines and are tilted toward the south. In most vineyards approximately 22 lb. of fruit are placed on each tray.

The grapes must be spread evenly and to a depth of one bunch only. Picking is done by piecework, the usual price per tray being 3½ cents or approximately $3.15 per fresh ton.

A short knife with curved blade or a pair of stout, short shears are used for cutting the bunches of grapes from the vines.

Turning.—After the grapes have partially dried, the trays are turned by placing an empty tray over a filled tray then quickly and deftly reversing the trays and removing the empty tray. The bottoms of the bunches are thus exposed to the sun and drying is hastened and made more uniform. Under usual drying conditions about 4 to 6 days' exposure to the sun is required before the grapes are ready to turn.

Turning should be carefully done, so that the bunches will be broken as little as possible and a maximum yield of cluster raisins obtained.

Stacking.—As in the drying of other fruits in the sun, the last stages of the drying process are conducted in the shade, *i.e.*, by stacking the trays in order to protect the fruit against the direct rays of the sun. Stacking is done when it is no longer possible to express juice from the berries by pressure between the fingers, which will be normally 5 to 6 days after turning. The grapes are left in the stack until sufficiently cured to be accepted by the packing house, usually after about 1 week in the stack. The total drying period under normal drying conditions is therefore about 3 weeks. In cool weather it may require 6 weeks to dry the grapes sufficiently and in very hot weather less than 3 weeks.

Placing in Sweatbox.—There is a good demand for raisins in the bunch for fancy packages for the holiday trade. These raisins are used for dessert purposes and are known as "layers" or "clusters," and the grower is paid a premium for such fruit. When the grapes are dry (about 15 to 17 per cent moisture), the trays are sorted to remove the large and perfect clusters, which are placed in sweatboxes, care being taken not to break the bunches.

Raisins not suitable for clusters are dumped into sweatboxes. The raisins are very easily removed from the trays, as there is no tendency for the fruit to stick to the smooth wooden shakes used for tray bottoms and

because the grapes are not dipped and therefore do not exude juice or syrup, as do prunes and cut fruits.

Sweatboxes.—Sweatboxes are almost universally used as containers for the raisins. These boxes are approximately 3 by 4 ft. and about 10 in. deep, about 150 lb. of raisins being placed in each sweatbox. By pressing the raisins, the box can be made to hold a larger quantity, but this practice is objectionable because it may result in breaking of the berries and stems, making it difficult to stem the raisins in the packing house.

The raisins should be left in the sweatboxes for at least 3 weeks before delivery to the packing house in order that they may equalize in moisture content and remain fairly constant in moisture content during storage at the packing house.

Cost of Producing Muscat Grapes.—Table 59 gives typical cost data for the production of Muscat raisins in California in 1920. Costs are considerably less at present.

TABLE 59.—COST OF MUSCAT RAISIN PRODUCTION FOR YEAR 1920
(On basis of 1 acre and yield of ¾ ton per acre)
(*After D. H. Gray*)

Labor	$ 67.43
Taxes and insurance	11.82
Depreciation, total	27.88
Interest	48.00
Management	32.05
Miscellaneous	46.40
Total	$233.58

The return for a ¾-ton crop at 11 cents per pound is $165, yielding a net loss of $68.58 per acre. Similarly a 1-ton per acre crop yields a loss of $22.10 and a 2-ton crop a profit of $163.65, according to Gray. Present costs are about one-half those given in the table.

Drying of Seedless Grapes in California.—The principal seedless variety grown in California is the Sultanina or Thompson Seedless, a variety which comprises more than 90 per cent of the total crop of seedless grapes in that state. The Sultana is second in importance. Two varieties of currant grapes, the Black Corinth and the White Corinth, are grown in very small quantities.

Undipped Sultanina.—The Fresno district is the principal producer of Thompson Seedless raisins, where most of the seedless grapes are dried in the same manner as described above for the Muscat grape. The grapes are not dipped in lye or otherwise treated before drying, but are picked direct from the vines on the trays. In some vineyards paper trays made of heavy wrapping paper are used, and these are of the same dimensions as the wooden trays. They are much less satisfactory than the wooden trays and their only merit is their low original cost.

Thompson seedless grapes should not be picked until the juice has attained at least 24° Balling.

Because of the larger size of the bunches a larger weight of Sultanina grapes than of Muscats can be placed on each tray. The Sultanina yields more heavily than the Muscat and plantings of this variety have been much heavier than of Muscat.

Soda-dipped Sultanina Raisins.—In the Sacramento Valley of California grapes ripen 2 to 3 weeks later than in the Fresno district in the San Joaquin Valley. Most of the grapes are, therefore, lye dipped in order to hasten drying, so that the grapes may be dried before the rainy season.

Lye Solution.—At the dry yard the grapes are dipped in a boiling dilute lye solution in a manner similar to that described elsewhere for prunes. The concentration of the lye varies from about 0.1 to about 0.75 per cent sodium hydroxide, the most desirable concentration being about 0.5 per cent sodium hydroxide; or a mixture of sodium carbonate and sodium hydroxide is used in some yards. The length of immersion in the lye solution is from 3 to 6 sec., and the grapes are rinsed in water immediately after lye dipping.

Dipping Outfits.—The "merry-go-round" dipper, the most commonly used type of dipping outfit, consists of two or more hinged wire baskets suspended from the ends of levers which, in turn, are hinged to a central, pivoted upright. The baskets are filled with grapes, immersed in the boiling lye solution a few seconds, and rinsed in water, and the grapes are spread on 6- by 3-ft. trays.

The skins of properly dipped grapes should exhibit an evenly checked surface.

Spreading in Yard.—The trays are spread in the dry yard directly from the dipping shed and are turned after the grapes are from one-half to two-thirds dry, in normal drying weather 3 to 5 days after dipping. After 2 or 3 days' further exposure the trays are stacked to complete the drying process.

After drying, the raisins are transferred to lug boxes or sweatboxes and taken to the stemming and packing house, which is frequently part of the dry-yard equipment. The raisins are light brown in color and superior to the bleached raisins in flavor.

Oil-dipped Sultanina and Sultana Raisins.—So called "oil-dipped" raisins are prepared by dipping the fresh grapes in a cold solution of sodium bicarbonate on the surface of which is a thin layer or film of olive oil. The usual concentration of bicarbonate is 28 lb. per 100 gal.

This solution does not check or crack the skins of the grapes and apparently merely removes the wax and bloom. The grapes are coated with a very thin film of oil as they emerge from the dipping solution.

This causes the dried product to be light in color and of glossy appearance.

The grapes are dried in the sun, as previously described for lye-dipped Sultanina grapes.

In California the Sultana and Sultanina are different varieties. In Australia the grape known in California as the Sultanina is called the Sultana.

Bleached Sultanina Raisins.—There is a considerable demand among the Jewish population of the eastern United States for bleached seedless raisins, prepared by exposing lye-dipped Sultanina grapes to the fumes of burning sulfur for 3 to 5 hr. before spreading in the dry yard. Drying is conducted as described for the soda-dipped raisins.

A perfect specimen of bleached Thompson Seedless raisins should be translucent and white to very light amber in color. It should be dried sufficiently so as not to exude syrup when pressed between the fingers but should be tender, not brittle or tough. The flavor of the bleached raisins is not so pleasing as that of the unsulfured fruit.

The yield of dried fruit per acre of bearing vineyard is, in northern California, about 1½ to 3 tons.

Drying Grapes in Australia.—The process of drying grapes in Australia is described as follows by H. F. Levien, a prominent grape grower of Renmark, South Australia.

The following classes of raisins are produced: currants, Sultanas (lye dipped), Muscats, not dipped and Muscats (lye dipped). Lye-dipped Muscats are known as "lexias," an adaptation from the Spanish.

The hot dipping solution for seedless grapes is usually the so-called "mixed dip," consisting of 2½ lb. of potassium carbonate, 2 lb. of sodium hydroxide, 1½ pt. of olive oil, and 50 imperial gal. of water. The grapes are dipped at 178 to 181°F. and spread on trays or racks to dry.

Muscat grapes are usually dipped in a solution of 1 lb. of sodium hydroxide to 12 to 16 gal. of water at about 200°F. They are drained well and spread to dry.

Neither the seedless nor the Muscats are dipped sufficiently to crack the skins noticeably, whereas in California the dip is more severe, resulting in cracking of the skins.

At one time raisins were made by sun drying on 2- by 3-ft. trays, as in California, but owing to the heavy losses from rains and to the labor cost of stacking trays in inclement weather, a process peculiar to Australia has been developed. The grapes are dried on wire-netting racks beneath a sheet-metal roof or wooden shed. Wire netting of 2-in. mesh and 18 gauge is "strung," *i.e.*, fixed to heavy 6-gauge wire to give it rigidity and is fastened to posts by fixed or removable frames. Six or more tiers of the netting are used.

Currants are spread on the screens without dipping. Muscats (Muscat Gordo Blanco) and Sultanas are usually dipped in a dilute boiling lye solution and rinsed before spreading on the netting racks. Some Muscats are dried without lye dipping. A perforated metal bucket is used in spreading dipped grapes. Lug boxes are used for currants, as these are not lye dipped.

The fruit is not exposed to the sun but is dried by air currents which circulate freely between the racks. Currants require 14 to 21 days for drying, lye-dipped Sultanas about 10 days, and Muscats about 14 days. Undipped Muscats and Sultanas require considerably longer periods.

The color of raisins dried on racks is very attractive, is lighter than that of raisins prepared by sun drying, often some of the green color of the fresh grapes being retained, and the flavor is excellent.

The seedless grapes are also dried after dipping in a cold potash solution containing about ½ lb. of potassium carbonate per gallon of water and ½ to ¾ pt. of olive oil per 25 gal. of solution. The oil is thoroughly emulsified with the potash solution. The grapes are immersed in the solution for 2 to 5 min. at about 100°F. and are then dried on racks or trays. They are usually sprayed occasionally with dilute potash solution during drying. When dry, they are spread in the sun for a few hours to bleach the chlorophyll. They are then rinsed in water; dried in the sun to remove surface moisture.

The average yield of Muscat raisins per acre is about 1 ton, of Sultana about 1,800 lb. and of currants about 1½ tons. With improved methods of cultivation and care, it is possible to double the average yields.

The Australian raisins are marketed principally in England, New Zealand, and in Australia, but increasing production will undoubtedly force the growers to seek additional markets.

The dried-fruit producers of Australia are organized under the name of the Australian Dried Fruit Association and use the trade mark Sunraysed.

Sun Drying of Wine Grapes and Cull Table Grapes.—During the Prohibition period in the United States there was a demand for dried wine grapes for the preparation of homemade beverages. Wine grapes, principally of the red wine grape varieties, have been dried on an extensive scale in the raisin districts of California without previous treatment, by the same methods now in use for the drying of Muscat and Sultanina grapes. Sun-dried grapes produced by this method yield on soaking in water a juice of dark brown, not red, color, whereas consumers of these grapes desire a red juice for beverage purposes. In experiments made by the writer at the University of California Farm, it was found that the red color could be retained by dipping the grapes in lye and exposing the dipped grapes to the fumes of burning sulfur for about 1 hr.

before drying. Wine grapes require a 2 to 3 per cent lye solution for satisfactory checking of the skins.

While cull table grapes from the fresh-fruit packing houses are utilized for the manufacture of wine and brandy, they also are now sometimes dried in the sun or in dehydraters after lye dipping and have found a ready market as cheap raisins.

SUN DRYING OF FIGS

Smyrna has long been known as the world's principal fig-exporting port. The fruit is produced in Palestine and other districts of western Asia Minor. In recent years the production of dried figs in California has rapidly increased, and California is now a strong competitor of Smyrna in the markets of the United States.

Varieties of Figs for Drying.—The so-called fruit, the fig, is the fleshy receptacle enclosing a large number of very small flowers. The Smyrna fig (more properly, Lop Injir), a large white variety, is the principal variety grown in the Mediterranean countries for drying. It requires fertilization with the pollen of some other variety, accomplished by a small wasp which develops inside a male variety of fig grown for pollination purposes and known as the caprifig; on emergence from the latter, the insect carries on its legs and body pollen from the flower of the caprifig, the flowers of which are borne inside the fig. The insect, known as *Blastophaga grossorum,* escapes through the small opening in the blossom end of the caprifig, enters the eye of the immature Smyrna fig and pollinizes it. The Smyrna fig does not develop or ripen unless pollinized in the manner described above. The caprifig remains on the tree during the winter and serves as an abode for the Blastophaga, a fact which prevents extermination of the insect after the removal of the figs from the Smyrna trees.

The Smyrna variety is large, has an excellent flavor, and is attractive in appearance when packed. An objection to this variety when grown in a cool climate is its tendency to ferment, rot, and sour before drying.

"Calimyrna."—A strain of the Smyrna variety is grown in California under the name of Calimyrna. Its successful culture has been made possible by the studies of George Roeding of Fresno and G. P. Rixford of the U. S. Department of Agriculture. In recent years losses of the fruit in the orchards have been very heavy because of endosepsis, a disease carried into the figs by the Blastophaga wasp. Smith and Hansen of the University of California have devised a means of securing disease-free wasps and propagating them in quantity. However, their successful use depends also on destruction of all contaminated figs and wasps, a rather costly and troublesome procedure; yet not impossible of attainment.

Adriatic.—The Adriatic fig is a white variety of pink flesh. It requires no artificial pollinization; a large proportion of the seeds are sterile. It is inferior in size and flavor to the Calimyrna variety but is a heavy bearer and is grown extensively on that account.

Kadota.—The Kadota (according to Coit and Condit, the Dodatto) is a white variety now planted extensively in California for fresh shipment and for canning and preserving. It is on the average smaller in size than the Calimyrna and Adriatic varieties and requires no pollinization. It is the most satisfactory variety grown in California for canning and preserving, because of the fact that the walls of the fruit are thick and the seed cavity is small. A limited quantity only of the fruit is dried.

Mission.—The Black Mission fig, which has been grown in California since the days of the early Spanish mission, yields a dried product of black color, tender texture, and excellent flavor. The fig is not subject to souring or black smut and the trees yield heavily. The dried product is used with the white varieties for fancy mixed packs.

Harvesting.—Figs should not be picked for drying but should be allowed to ripen and partially to dry on the tree and fall to the ground of their own accord. If picked from the tree, the fruit is liable to sour on the trays or mold, and the dried product will be woody and of poor flavor. The orchard ground should be made as smooth as possible by rolling.

The fruit should be picked from the ground frequently and should not be allowed to lie on the ground more than 2 or 3 days because of danger of molding of certain varieties, toughening of the skin of other varieties, and danger of infestation with insects which gain entrance through the eye of the fig.

Dipping and Sulfuring.—Calimyrna figs are in some dry yards dipped in a solution of 10 lb. each of salt and hydrated lime per 100 gal. of water in order to remove some of the hairs from the surface, to improve the color, and to soften the skins. Some Adriatic figs are also dipped in a solution of the above or similar composition. Mission figs are not dipped before drying.

The figs are carefully sorted as they are spread on the trays, and the Adriatic figs are often, but not always, sulfured, in order to bleach the flesh and to sterilize them. It is believed that sulfuring checks fermentation and destroys insects and insect eggs. The trays are usually placed in the sulfur box in the evening and allowed to remain in the fumes of the burning sulfur overnight, 3 hr. or more sulfuring being necessary to accomplish the desired results. The Calimyrna fig should not be sulfured except under adverse drying conditions to prevent souring.

Protection against Insects.—Figs are subject to heavy infestation with insects. For protection of figs and other fruits see section at end of this chapter.

Drying.—As they arrive at the dry yard, figs are usually from one-half to two-thirds dry. On this account it is frequently possible to stack the trays immediately after spreading the fruit and to accomplish most of the drying in the stack. Exposure to the sun toughens the skin of the Calimyrna variety, and a dried product of better quality is obtained by drying the fruit entirely in the stack.

The figs are dried until firm and until juice or syrup can no longer be expressed with the fingers.

Sorting and Boxing.—The dried fruit is carefully sorted on the trays to remove bird-pecked, green, and split fruit and fruit showing evidence of smut. The cull fruit is of little value except for hog feed. In some yards the Adriatic figs are dipped in salt solution after drying and are sulfured before being placed in sweatboxes. Most of the fruit is, however, placed directly into sweatboxes from the trays. Figs should not be placed in sacks, as such treatment is liable to result in crushing of the fruit and in injury to its appearance.

Harvesting and Drying Figs in Asia Minor.—Roeding has briefly described the harvesting and drying of Smyrna (Lop Injir) figs in the following manner.

Harvesting.—Before harvesting begins, the orchards are weeded carefully so that the figs may be seen readily after they have dropped. The harvesting season begins about Aug. 5, but the best fruit is gathered in September.

The figs drop to the ground and are gathered in baskets holding about 50 lb. when filled, but the baskets are gathered only half full.

Dry Yard.—The drying ground is usually an open space in the orchard where a few trees have died and have not been replanted. Layers of rushes, about 2 in. thick and about 3 ft. wide with pathways between them, are prepared. The figs are dumped from the baskets on the rushes and are then spread by hand one layer deep.

The figs are stirred daily with the hands, and the small figs, which dry first, are removed. The usual length of the drying period is 2 to 4 days.

Storing.—The dried figs are usually stored in a small room in the dwelling of the owner or foreman. At the end of the season they are sorted into three grades for size and are packed in goat-hair sacks for shipment to the packing house.

None of the figs are packed in the fig-growing districts but are shipped to Smyrna and packed in special establishments for this purpose.

DATES

Dates require a hot, dry climate and an abundance of water supplied naturally or by irrigation. The Valley of the Nile, Tunisia and Algeria,

and the oases of the Sahara and Arabian deserts supply these necessary conditions and have, since the beginnings of civilization, been the world's principal source of supply for this fruit.

Varieties.—The most important variety grown in Arizona and California is the Deglet Nur (Deglet Noor in California) more properly, according to Popenoe, the Daqlet al Nur. This variety is grown extensively in Algeria and Tunisia. It is of medium size, mild flavor and, if properly cured, is of light amber color and translucent. Other important varieties are: the Ghars, a very large early-maturing variety; the Kasbeh, a good shipping date; the Khadrawi, from the Persian Gulf and successfully grown in California; and the Halawi, an Arabian variety. The fruit of the most desirable varieties is large, of good flavor, tender texture, and of good packing and shipping quality. Varieties that mummify or sour or ferment on the trees or become very soft and syrupy after packing are not desired.

Harvesting.—A few varieties ripen in California in July, but the principal harvesting season is in September, October, and November. The fruit is borne in large bunches on the end of a tough stalk, which is bent downward in the form of a bow from the weight of the fruit.

Ripening on Tree.—Unripe dates are green in color and very astringent owing to their high content of tannin. During ripening the tannin disappears to a large extent, the color of the date becomes brown, red, or amber and the flesh becomes soft, syrupy, and translucent.

Some varieties tend to dry on the tree to a leathery texture instead of to the usual desirable soft texture. This "mummifying" can be prevented by irrigation during ripening.

It is sometimes necessary to cover the bunches with cheesecloth bags to exclude birds and insects.

Early rains may cause souring of the dates or make it necessary to harvest them unripe and to ripen them artificially.

According to J. E. Coit, the usual methods of harvesting dates in the southwestern United States are as follows:

Picking and Fumigating.—In the Coachella Valley in California the weather is usually so dry during ripening time that the fruit loses moisture as it matures and mummifies on the trees, becoming like dry bread dates. While dry Deglet Noors are quite appetizing, the market demands them soft and translucent, the condition in which imported Deglet Noors reach this country. In one large plantation the dates are picked every 3 days, selecting those which are completely ripe but before they have hardened. They are then fumigated in a cabinet with carbon disulfide, ½ oz. to the cubic foot, for 2 hr. to sterilize the fruit and kill any insect eggs which may be present.

Ripening.—The fruit is then placed in specially made tight wooden boxes. The boxes are then placed in an ordinary poultry incubator and kept from 3 to 5 days at about 96°F. The chemical reactions taking place in the dates during this time may possibly result in water being formed, for the dates go in dry and firm and come out soft, moist and beautifully translucent with a delightful aroma, which is characteristic of the Deglet Noor. The dates are then graded and packed in fancy 1-lb. boxes as fresh dates for immediate sale. A temperature somewhat below 100°F. for several days seems to give better results than a higher temperature for a shorter time. Dates to be packed as dry dates are placed in a dehydrater directly from the tree and dried at about 110°F. to the desired moisture content. During drying they lose their astringency and become semitranslucent.

In some groves the dates ripen sufficiently on the trees and can be packed as fresh dates without ripening at 100°F. as described above.

Packing.—After being sterilized by fumigation, as previously explained, they are placed in a drier at about 110 to 120°F. and the excess moisture quickly driven off. They are then sorted into grades, the best being carefully packed in fancy confectionery boxes. The second grade is packed in bulk in 50-lb. wooden candy tubs, or utilized for by-products. As explained before, it is essential that the varieties handled in this way have a high sugar content. If they are low in sugar, they shrivel when dried sufficiently to keep indefinitely without fermentation.

Insect Injury.—In Arizona a small brown beetle (*Carpophilus dimidiatus*) works its way under the skins or into the opening at the base and lays eggs that hatch later into grubs which accelerate souring. In California the same insect together with the Indian-meal moth (*Plodia interpunctella*) has proved very troublesome. All packing rooms should be thoroughly screened, and after pasteurization or fumigation the dates should not leave the screened room until packed. It is important to see that the containers are insectproof.

Glass-packed Dates.—Deglet Noor and similar varieties are now also packed in glass jars without previous drying. The product is moist and possesses the rich flavor of the fresh date.

The dates are allowed to ripen on the tree or on the bunch after removal from the tree. They are picked carefully and are not dried before packing. They are packed into glass jars which are heated to 165°F. and sealed under vacuum, no further processing being necessary.

Date By-products.—Dates of second quality are in some packing plants pitted mechanically, dried "bone dry," and broken into pieces about ⅛ to ¼ in. in diameter for use by bakers. Also they are canned as a paste after pitting, grinding, and mixing with invert sugar syrup.

Brandy of good quality can be made from dates. It is known as "arrack" in the Near East, where it is flavored with anise seed.

SUN DRYING OF APRICOTS

Although most of the dried apricots consumed in America are produced in California, this fruit is also dried commercially in France, Australia, and Asia Minor. It has been an important article of diet in Asia Minor for many centuries.

Varieties.—In California the Royal, Blenheim, Tilton, and Moorpark are the principal varieties used for drying. The Hemskirk and Peach varieties are grown in limited quantities only. The above varieties are described in Chap. XI.

In the coast counties of central California (Santa Clara, Alameda, Napa, San Benito, and Sonoma counties) the Blenheim is preferred to all other varieties. In southern California and in the hot interior valleys, the Royal is the principal variety used for drying.

Harvesting.—The fruit should be allowed to remain on the trees until "eating ripe," *i.e.*, somewhat riper than for canning purposes. Apricots should be picked frequently, so that the fruit shall be neither too ripe nor too green, since underripe fruit yields a badly shriveled, tough, dried product of poor flavor and overripe fruit forms "slabs" during drying. Slabs, while of excellent flavor and color, are of unattractive form and must be sold at a low price.

Cutting and Traying.—The fruit in the lug box is placed beside the cutter on a level with the tray, or part of the box may be dumped on the tray. Fruit and empty trays are brought to the cutters, and filled trays are removed, by men or boys assigned to these duties. The cutters' only duties are to cut the fruit in half around the suture, remove the pits, and spread the cut halves on the trays with cups upward. The knife should be run completely around the fruit to the pit, in order to give smooth edges to the cut fruit. Cutters average from 600 to 1,200 lb. per day, and the cost of cutting varies from $5 to $7 per ton.

In most yards trays are 8 by 3 ft. in size, and the fruit is spread one layer deep. Each square foot of tray surface will hold about 2 lb. of cut fruit.

The pits are placed in lug boxes and are later spread on trays and dried in the sun for sale to by-product factories.

Sulfuring.—The filled trays are stacked on dry-yard cars and placed in a sulfur box, where the fruit is exposed to the fumes of burning sulfur at least 3 hr. The last cars to enter the sulfur houses in the afternoon remain overnight. The fruit should be sulfured until the cups fill with juice or until the flesh is permeated with sulfur dioxide, as shown by the

change in color and texture of the flesh examined, when several halves are cut in two.

Approximately 5 to 8 lb. of sulfur per ton of fruit are normally required but the length of exposure to the fumes and the concentration of SO_2 in the fumes are, however, far more important than the weight of sulfur used.

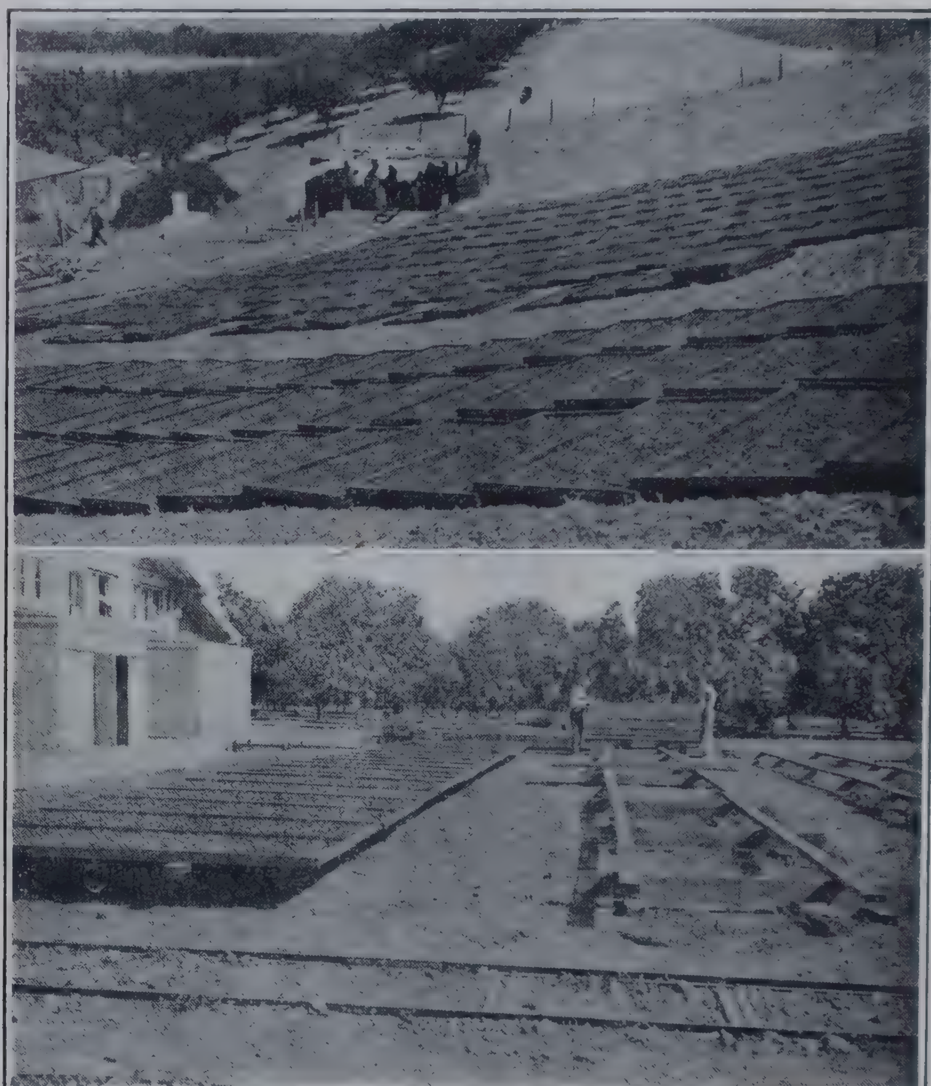

Fig. 78.—Apricot drying yards. Note tray racks in lower picture.

Properly sulfured apricots should not turn brown during or after drying and should retain the clear golden yellow of the fresh fruit. Sulfuring does not bleach the carotene pigment of the apricot but merely prevents darkening of other pigments.

Drying.—The apricot ripens in July and early August in California, *i.e.*, in midsummer; consequently no difficulty is experienced in obtaining sufficient sunshine for drying the fruit.

The trays are spread in the sun for 1 to 4 days, which intensifies the golden color of the fruit and changes green fruit to a golden-yellow color, in addition to causing drying.

When the fruit is one-half to two-thirds dry, the trays are stacked in such manner that the prevailing wind may pass freely between them.

Properly dried apricots should be soft and pliable but not sticky, and when a handful of the fruit is squeezed, it should not stick together when the pressure is released. When an individual piece is pressed between the fingers, it should not be possible to obtain juice or syrup. On the other hand, the fruit must not be overdried. It should contain about 18 per cent moisture.

Sorting, Boxing, and Sweating.—When most of the fruit is sufficiently dry, it is carefully sorted, slabs being placed in a separate box. Fruit which requires further drying is returned to the trays, and the properly dried fruit is scraped from the trays with wooden paddles or steel scrapers into lug boxes.

The dried apricots are stored in bins or in heaps on a wooden or concrete floor to undergo sweating for several weeks before packing or delivery to the packing house. Sacks are usually employed as containers for delivery of the fruit.

Yields and Costs.—The usual drying ratio is about 5:1. According to a survey of a number of California dry yards made by A. W. Christie and L. C. Barnard of the University of California, the average cost of harvesting and drying for two seasons was $80 and $88.94 per dry ton.

In large, efficiently operated dry yards these costs can be reduced; in small inefficiently operated yards the costs will be greater. The costs and yields also vary considerably from year to year and with the locality.

Unpitted Dried Apricots.—Occasionally very small apricots are dried whole without cutting in half or pitting. The fruit is first dipped in lye as described elsewhere for prunes, is then sulfured 6 to 10 hr., and is dried in the sun in the usual manner. The product is satisfactory for preparing and serving in the same manner as dried prunes, but the market is limited.

Apricot "Leather."—In Asia Minor ripe apricot pulp is dried on smooth boards in the sun to a leathery consistency in the form of sheets, which are then rolled for convenience in packing. The "leather" is eaten as a confection or is cooked in the form of a sauce.

SUN DRYING OF PEACHES

Most of the sun-dried peaches of California were formerly sold through a cooperative association known as the California Peach and Fig Growers' Association, under the Blue Ribbon brand, but at present most of the dried fruit is packed by independent packers.

Australia and South Africa are increasing their output of sun-dried peaches and are following California methods of drying and marketing.

Varieties.—A peach suitable for sun drying should be a freestone variety of large size and high sugar content. It should be pulpy, rather than juicy, with flesh of rich golden-yellow color and of pleasing flavor.

The Muir peach most nearly fulfills these requirements, and more than 60 per cent of the dried fruit produced in California is of this variety. The Lovell is second in importance to the Muir. Other important varieties are the Crawford, Foster, Salway, and Elberta. One of the principal objections to the Elberta is the red color of the pit cavity.

Clingstone varieties cannot be pitted economically and give a low yield of dried product because of their low sugar content. Nevertheless, considerable quantities are dried in dehydraters (see next chapter).

Harvesting.—Peaches should be picked when they have become slightly soft to the touch over the entire surface. They are firmer than apricots, but when bruised, even slightly, the flesh darkens quickly. They must, therefore, be handled with great care and should be cut and spread on trays as soon after picking as possible.

Several pickings should be made during the season in order to insure a dried product of highest quality. Although much of the fruit is knocked with poles or shaken from the trees, this method should not be used, because it not only results in bruising the fruit but removes a large proportion of green fruit, which gives a dried product of unattractive gray color, poor flavor, and woody texture.

Insect Infestation.—Peaches are subject to severe damage by insects. See page 459 for control measures.

Cutting, Traying, and Sulfuring.— The cutting and traying operations are conducted as described elsewhere for apricots, the cost of pitting being less because of the larger size of the fruit. The halves are placed with cups upward on trays 8 by 3 or 6 by 3 ft. in size.

Peaches are sulfured 4 to 6 hr. or overnight. A longer period of sulfuring is required than for apricots because of the larger size of the halves.

Clingstone peaches are pitted and lye peeled as for canning. They must be sulfured at least 5 hr. They are usually dehydrated instead of sun-dried.

Drying and Sweating.—The method of drying is identical with that described elsewhere for apricots, although the drying period is somewhat longer. As much of the drying should take place after stacking as possible, in order to obtain a dried product of highest quality.

A well-dried peach should be golden yellow, not gray-green or brown, and firm and pliable but not syrupy or sticky.

The fruit is sorted on the trays after drying and placed in sweatboxes, in bins, or in piles on the floor to undergo sweating before delivery to the

packing house. The fruit continues to lose moisture during this storage period.

The usual drying ratio is about 4.5:1 but will vary from 3.5:1 to 7:1 according to the variety and its maturity. The Muir and Lovell varieties yield more heavily than the Elberta.

Costs.—Christie and Barnard have collected data on drying costs in California. Their averages are: cutting cost $3.34 to $3.46 per green ton, dry-yard labor $1.33 per green ton, and total cost of picking and drying, $13 per green ton.

SUN DRYING OF PEARS

The Bartlett pear is the most important variety grown commercially for sun drying, but dried pears are very much less important than dried apricots, prunes, figs, and raisins.

In most pear-growing sections of California the pears used for drying are the culls from fresh-fruit packing houses and canneries. In Lake County in California, however, because of lack of transportation facilities a large proportion of the entire crop is utilized for drying.

Harvesting.—Bartlett pears are harvested while still too green for eating and are allowed to ripen after picking. If to be used for drying and not for fresh shipment, the fruit should show beneath the background of green a faint to pronounced yellow color but should still be too firm for eating fresh.

Ripening and Sorting.—Cull pears are usually placed in lug boxes to ripen or on straw in rows about 1 ft. wide and 6 in. deep and are covered with straw. As the fruit ripens it is sorted two or three times. Usually a week to 10 days is required for ripening, although wormy and sunburned fruit will ripen in less time.

In Lake County the fruit is allowed to ripen in lug boxes stored beneath a shed and is sorted frequently in order to obtain prime ripe fruit.

The loss in sorting amounts to 3 to 25 per cent, depending upon the quality of the fresh fruit and frequency of sorting.

In some of the large dry yards the pears are graded for size by a mechanical grader before ripening. Large pears require a longer period of drying than small ones, hence the desirability of placing on each tray fruit of uniform size.

Treatment to Remove Spray Residue.—Bartlett pears are heavily sprayed several times during the spring and summer; consequently they carry considerable poisonous spray residue (lead arsenate) which must be removed before the fruit is cut and dried. This is accomplished by passing it through a tank of dilute hydrochloric acid, about 0.5 to 1.0

per cent of the acid, for 1 to 3 min. and rinsing in water; or by applying the acid solution and water by pump-driven sprays.

Cutting and Traying.—The pears are cut when they have become "eating ripe," but before they have become "mushy." Overripe fruit produces slabs, whereas underripe gives a dried product of woody texture and poor flavor.

The fruit is cut in half lengthwise but is not peeled. In most dry yards the stem and calyx are removed, but the fruit is not cored.

The pears are spread with the cut surface upward on trays 8 by 3 ft. in size.

Sulfuring.—The fruit and trays should be thoroughly sprinkled with water before they enter the sulfur house, in order to facilitate absorption of the sulfur dioxide. In some yards the cut fruit is dipped in or sprinkled with dilute brine, as salt retards darkening.

In Sacramento and Contra Costa counties, where cull pears are used, the fruit is sulfured from 8 to 24 hr. and in Lake County 48 to 72 hr., the sulfur being replenished at about 8-hr. intervals. Recent data taken by this laboratory indicate that with tight sulfur houses the time can be greatly shortened. A pear properly sulfured before drying is very soft throughout, since sulfuring softens the tissue very markedly. The market demands a dried pear that is very light in color and nearly transparent, a condition that can only be obtained by the excessively long periods of sulfuring noted above.

Drying.—In the method used in Lake County, California, the pears are spread in the sun for from ½ to 2 days. The trays are then stacked beneath long sheds open at the sides and so placed that air may circulate freely between the trays. Three to six weeks' time is required to complete the drying process, the slow drying in the shade in this manner producing a dried pear that is nearly transparent and very attractive in appearance.

In the Contra Costa County process the pears are spread in the sun until one-third to two-thirds dry before the trays are stacked. Drying is accomplished in a shorter time than in the Lake County process, but the dried product is less translucent and is of darker color.

Because of heavy sulfuring, dried pears do not undergo molding or fermentation readily and need not be dried to so low a moisture content as peaches or apricots before removal from the trays. A properly sun-dried pear should be pliable, of tender texture, light color, and translucent. A chalky-white or brown color is not desired by the trade.

MISCELLANEOUS FRUITS

Cherries.—Split, overripe, and rain-damaged cherries are dried in the sun to a limited extent in California.

Preparation of cherries for sun drying consists in dipping the fruit in a boiling dilute lye or sodium carbonate solution to check the skins. White cherries, such as the Royal Anne, are improved in appearance if sulfured for about 1 hr. after lye dipping. Black varieties need not be sulfured. Drying is conducted as described elsewhere for prunes.

Berries.—Raspberries, strawberries, and loganberries are frequently sun-dried for home use. The untreated fruit is spread on wooden trays in the sun until about two-thirds dry. Drying is then completed after stacking the trays. L. C. Barnard, of the University of California, has found a dried product of improved color and flavor is obtained if the fresh berries are sulfured for about 1 hr. before drying.

All berries are of much more attractive appearance and better cooking quality if dehydrated.

Persimmons.—The Japanese dry large quantities of persimmons, which are used as a confection and food. The ripe fruit is peeled and threaded on strings which are hung in the shade until the fruit is dry. The fruit must not be sulfured or it will remain astringent.

Protection of Drying Fruit from Insect Damage.—Fruits exposed on trays, either in the open or when stacked, are subject to insect attack. Insects may lay their eggs on the drying fruit. These eggs hatch, and the resulting larvae may greatly damage the fruit by eating it and marring its appearance by webbing. The Federal Food and Drug Administration has established maximum tolerances for insect infestation in dried fruits and in fig paste.

The raisin moth (*Ephestia figulella* Gregson) is particularly obnoxious. It multiplies early in the summer in mulberries that have fallen from the trees and dried. Such trees near dry yards should be eliminated. The Indian-meal moth (*Plodia interpunctella*) is also a serious dried-fruit pest, but it is a packing-house pest rather than dry-yard pest.

It has been shown by Simmons and associates of the U. S. Department of Agriculture at Fresno, Calif., that cut fruits can be protected very effectively against dry-yard insect infestation by covering the fruit and trays with tobacco shade cloth after the trays have been stacked.

Sweatboxes of raisins were also protected in similar manner satisfactorily. Raisins in uncovered boxes in one test by Simmons and others showed many more insects per ton than the covered raisins.

Elimination of all waste fruits from the fields and orchards is very desirable, since such removal robs the insects of material in which to propagate.

The raisin moth infests the fruit principally after the trays have been stacked.

Simmons and associates recommend that any dried fruit to be held in storage be fumigated at once. Fumigable storage rooms are highly

desirable, as it is then possible to refumigate the fruit at intervals. The storage room should be screened and rendered as nearly insectproof as possible.

The dried-fruit beetle (*Carpophilus hemipterus* L.) infests figs during drying and storage. It breeds prolifically in piles of discarded grape pomace or in souring fruit wastes of any kind. The insects travel several miles from their breeding places and thus may infest fruit over a large area from a single focus. Fumigation of the figs as soon as gathered is one protective measure; another is elimination of waste fruits used as breeding places by the insects.

Formerly carbon bisulfide was generally used as a dried-fruit fumigant; later hydrogen cyanide gas was used. The former is very explosive and the latter is poisonous to man, hence extremely dangerous to use in farm dried-fruit storage rooms. It has been found that the fruit retains an appreciable amount of hydrogen cyanide when it is used as a fumigant.

Ethylene oxide may be used with greater safety than carbon disulfide or hydrogen cyanide. Nichols suggests 4 lb. per 1,000 cu. ft. of room space if the room is not exceedingly tight; and 2 lb. if the room is practically leakproof. Chloropicrin, tear gas, used at the same dosages as the ethylene oxide is also effective, although it must be handled with greater care as it is very irritating to workmen and animals. The fumigation should last 8 to 24 hr.

Ethylene dichloride and carbon tetrachloride mixture, 3 of the former to 1 of the latter, is also used. The dosage is 15 to 20 lb. per 1,000 cu. ft. It is not explosive and is not irritating to the mucous membrane. It has an anesthetic effect on man similar to that of chloroform. Methyl bromide is very effective, but is too toxic to man for safe use on the farm.

Fly sprays should never be used near or on dried fruits as they leave disagreeable odors and flavors.

Figs should be fumigated not only before but also after drying. See also pages 517 to 520 on fumigation of dried fruits at the packing house.

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CHAPTER XXI

DEHYDRATION OF FRUITS

As the Civil War of United States in the sixties stimulated the canning industry, the Boer War and the World War stimulated the dehydration industry. To conserve cargo space and transportation facilities, enormous quantities of foods were dehydrated during the World War and shipped to the Allied Armies in Europe.

In Germany in 1898 there were, according to Prescott, only three drying plants. In 1917 the number had increased to about 1900, a fact which explains in part Germany's ability to maintain her food supply during the war.

The dehydration of fruits has become a well-established and growing industry. Apples have been dehydrated (or "evaporated") in America for at least a century, and the dehydration of prunes in the Pacific northwest is an old and very important industry.

Definitions.—"Dehydration" is at present defined industrially as drying by artificially produced heat under carefully controlled conditions of temperature, humidity, and air flow. To dehydrate means to remove water.

The term "dried" is applied to all dried products, regardless of the method of drying.

Evaporation is usually considered industrially to mean drying under conditions of humidity, temperature, and air flow not so carefully controlled as in dehydration. Evaporation is a broader term than dehydration. If applied literally, the evaporation of fruit would mean the complete vaporization of the whole fruit, both water and solids. Alcohol, ether, and other liquids, as well as water, may be evaporated.

Desiccation is essentially equivalent in meaning to dehydration.

The terms "drier," "dehydrater," and "evaporator" are at present used more or less indiscriminately, although the term "drier" is often considered to be a general one applicable to all types of drying apparatus and a dehydrater is often considered to be more efficient and to permit of more exact regulation than an evaporator.

Relative Merits of Sun Drying and Dehydration.—At the present time most dried fruit is dried in the sun by the methods described in Chap. XX, but dehydration is rapidly increasing in importance because of its following advantages: (1) Dehydrated fruits, when cooked more

nearly resemble the cooked fresh fruit in flavor and color than do cooked sun-dried fruits; (2) they are generally produced under more sanitary conditions than sun-dried fruits; (3) dehydration permits of more careful control of the quality of the finished product; (4) less land and fewer trays are required for dehydration than for sun drying; (5) in seasons of early rains, the use of dehydraters prevents loss through rain damage.

Relative Cost.—Dehydration has usually been somewhat more costly than sun drying, but undoubtedly the superior cooking quality of the dehydrated products will cause them to command a sufficiently higher price to more than counterbalance the slightly greater cost of production.

Relative Yields.—Dehydration usually gives a somewhat higher yield of dried product (calculated to a common moisture content) than is obtained by sun drying, even under ideal sun-drying conditions. This difference is due probably to loss of sugar in sun drying through respiration or fermentation. During cloudy or rainy weather loss of sugar in sun drying through fermentation becomes excessive.

For the small orchardist the cost of sun-drying trays is usually less than that of a dehydrater, but for the large operator the cost of the dehydrater may in some cases be no more than that of sun-drying trays. Costs of construction will be discussed in greater detail later in this chapter.

Color.—During sun drying of green or slightly immature cut fruits, such as peaches and apricots, the fruit acquires the color of the fully mature fruit. In dehydration the fruit retains the color possessed at the time of cutting, fruit of green color retaining this color after dehydration. It is, therefore, essential that fruit used for dehydration be fully mature.

Cooking Quality.—The dehydrated fruits in all cases are superior to the sun-dried for cooking purposes, although not always equal to or superior in appearance before cooking. Comparison should be made of the refreshed and cooked fruits rather than the dried fruits.

PRINCIPLES OF DEHYDRATION

A thorough knowledge of dehydration is not possible without an understanding of the fundamental physical and chemical principles involved.

Advantages of Air as a Drying Medium.—Foods may be dried in (1) air, (2) in superheated steam, (3) *in vacuo*, (4) in inert gases, or (5) by direct application of heat. Air, however, is the usual medium employed industrially for the following reasons: It is cheaper and more convenient to install and operate dehydraters using air as a drying medium; where air is used, overheating is avoided; air can be used to conduct heat to the product to be dried and to conduct the liberated moisture from the product undergoing drying; no elaborate or costly moisture condensers are required when air is used as the drying medium; the use of air per-

mits gradual drying and thus avoids loss of juice by dripping; the use of air also reduces the tendency for fruits to discolor and scorch.

Functions of Air in Drying.—Air has two principal functions in the drying of fruits or other foods. It conveys heat from the furnace room or other heating device to the product and thereby causes the water in the product to vaporize, and it also serves as a vehicle for the transfer of moisture to the outside atmosphere. Both functions are important and necessary.

Relative Volumes of Air for Heat Conductance and Transportation of Water Vapor.—A larger volume of air is required to conduct heat to the drying chamber than to transport water vapor from the drying chamber, as illustrated in the following discussion.

For example, if dry air enters the drying chamber at 150°F. and leaves at 110°F. (a drop of 40°F.), approximately 1,750 cu. ft. of air are required to furnish enough heat to evaporate 1 lb. of water, while at 110°F. only approximately 235 cu. ft. of air (dry on entry to the dehydrater) are required to transport 1 lb. of water vapor. The ratio of air required to supply heat to the air required to remove liberated moisture is in this case about 7:1.

If, however, the entering air is not perfectly dry or if the escaping air is not saturated, the ratio becomes lower.

Since more air is required for transportation of heat than for transportation of moisture, the former amount must be used in calculating the air requirements of a given dehydrater.

For simplicity, the above calculations disregard the slight differences in volume of air caused by differences in temperature, and slight differences in the specific heat of air occasioned by differences in relative humidity. Increase in temperature increases the volume of air in accordance with the law of Gay-Lussac, *i.e.*:

$$V = V_0(1 + 0.003665t)$$

where V = volume at temperature (t) and V_0 = volume at 0°. The formula is based on centigrade temperature.

Expressed in a different manner, the volume of any gas maintained at constant pressure increases $\frac{1}{273}$ in volume for each 1°C. rise in temperature. For this reason it is often convenient to express air measurements in terms of weight, *e.g.*, as kilograms or pounds, which can, when desired, be converted into cubic meters or cubic feet.

Necessity of Heat.—It should be borne in mind that it is heat that produces evaporation and not the air or any mysterious property assigned to a vacuum. Approximately 1000 B.t.u. of heat are required to change 1 lb. of water to vapor, and this figure is known as the latent heat of vaporization of water. The latent heat of vaporization will vary some-

what with the temperature at which evaporation occurs, but at the temperatures used in the drying of fruits and vegetables an average of about 1000 B.t.u. may be taken for purposes of calculation of air requirements, etc. A British thermal unit (1 B.t.u.) is the amount of heat required to raise the temperature of 1 lb. of water 1°F. Table 45 gives the relation of temperature of evaporation to heat required for the evaporation of 1 lb. of water.

These amounts are required regardless of whether the product from which the water is evaporated undergoes boiling or not. The mere fact that heat is conducted to the product by air, and evaporation of the moisture from the product occurs without boiling, does not alter the amount of heat required for evaporation.

It is possible to dry fruit or other materials with air at atmospheric temperatures without previously heating the air. In this case the air will drop in temperature, and if this fact and the weight of the air are taken into account, it will be found that the evaporation process has taken the normal number of heat units and that the air possesses no miraculous power of "absorbing" moisture without the use of heat. Heat in this case comes from solar energy, since the atmospheric air has been heated by the sun's rays.

Volume of Air Required.—The volume of air required for the evaporation of 1 lb. of water will vary greatly with the temperature at which evaporation takes place, owing to expansion in volume with increase in temperature. If the calculations are, however, based upon the weight of the air and only the final results expressed in volume, calculations are greatly simplified. In most dehydraters all the heat required for the evaporation of moisture is obtained from heated air, the work done in evaporating moisture causing a drop in temperature of the air. This drop is a function of the amount of moisture evaporated and can be calculated if the other conditions are known.

Ridley has calculated the air requirements for a typical tunnel, air-blast dehydrater as follows:

One cubic foot of air at 60°F. requires 0.01807 B.t.u. to increase its temperature 1°F., and conversely 1 cu. ft. of air dropping 1°F. will release 0.01807 B.t.u. of heat.

Condition in Tunnel Drier.—If we assume a condition in which the air enters the dehydrater at 60°F. and is heated to 160°F., at which temperature it enters the tunnel, and is exhausted from the dehydrater at 120°F., the temperature drop will be 40°F.

The heat required to evaporate 1 lb. of water at 60°F. is 1058 B.t.u., and the heat required to heat 1 lb. of water from 60 to 160°F. and evaporate this amount of water at the higher temperature is 1102 B.t.u., the heat units necessary decreasing with rise in temperature. Assuming a

mean value of 1080 B.t.u., the number of cubic feet of air required will be 1,080/0.01807, or approximately 60,000 cu. ft. dropping 1°F., equivalent to 1,080/0.01807 ÷ 40 or 1,500 cu. ft. of air dropping 40°F. This is assuming that the air is measured at 60°F. If it is measured at 160°F., a much larger volume is required because of the expansion of the air through rise in temperature. Thus 1,500 cu. ft. at 60°F. becomes 1,805 cu. ft. at 160°F. The volume at any other temperature can be calculated by Gay-Lussac's law.

In addition to the heat required for the evaporation of water, heat is required for heating the trays, cars, and tunnel walls to the temperatures used during drying.

Air Requirements for Prunes.—Assuming that the dehydrater holds 10 tons of fruit, that it is desired that the fruit be dried in 24 hr. under the temperature conditions noted above, and that the drying ratio of the fruit is 2½:1 (*i.e.*, 2½ lb. of fresh fruit yields 1 lb. dry), the amount of moisture to remove per 24 hr. is 12,000 lb., or 8.3 lb. per minute. With a temperature drop of 40°F., there will be required 8.3 × 1,500, or 12,450 cu. ft. per minute. This is a minimum requirement and does not take into account losses of heat by radiation and leakage and that required to heat the cars, trays, etc., to the temperature of the dehydrater. Experience has proved that this quantity should be increased in actual commercial practice to at least 15,000 cu. ft. per minute, and preferably to 20,000 cu. ft. per minute, in order to dry the fruit in the required time of 24 hr.

Other Fruits.—Apples, peaches, apricots, and most other fruits possess drying ratios of 5:1 or 6:1. Therefore, the air requirements will be considerably larger for these other fruits than for prunes. With a drying ratio for apples of 6:1 and a drying time of 10 hr., it would be necessary to remove 16,666 lb. of water per 10 hr., or 27.7 lb. per minute. This would require, with a temperature drop of 40°F., not less than 41,500 cu. ft. per minute. In a similar manner the air requirements for other fruits or for other temperature conditions can be calculated.

Air Velocity.—In dehydraters tested in California in 1920 and 1921, it was found that the air velocity varied from less than 20 ft. per minute to nearly 1,000 ft. per minute. The velocity was measured by means of an anemometer, an instrument equipped with a small disk-type fan, as shown in Fig. 79.

Air velocity can also be determined from measurement of the air pressure in the drying compartment by means of a Pitot tube. A description of this instrument will be found in this chapter in the section on Air Pressure.

Velocity Equation.—It has been found that the rate of evaporation of water from a free surface is directly proportional to the velocity of

the air, other things being equal. This relation may be expressed by the following equation (according to Carrier):

$$W = 0.093\left(1 + \frac{v}{230}\right)(e' - e)$$

where W = pounds evaporated per square foot per hour, v = velocity of air over surface in feet per minute; e' = vapor pressure of water corre-

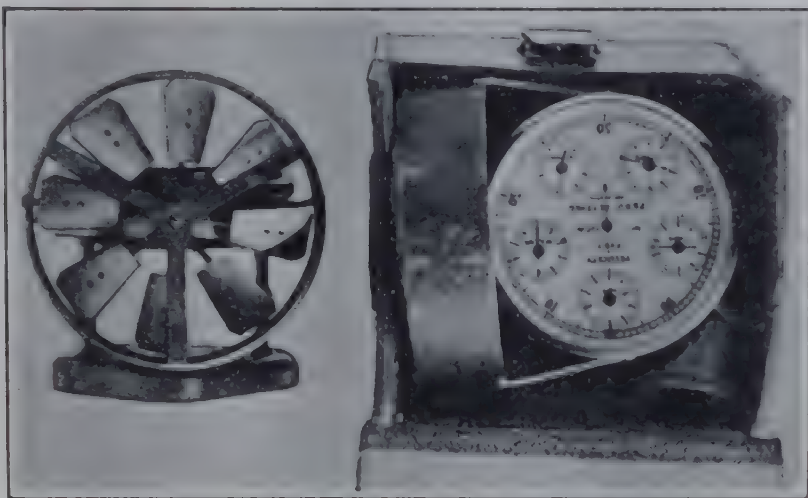

FIG. 79.—Anemometer for measurement of air flow in dehydraters.

sponding to its temperature; e = vapor pressure in the surrounding atmosphere.

Thus at an air velocity of 230 ft. per minute, drying is twice as rapid as in still air, and at 460 ft. per minute it is three times as fast as in still air.

TABLE 60.—EXAMPLES OF AIR-FLOW MEASUREMENTS AND DRYING TIMES
(*After Cruess and Christie*)

Plant	Type of dehydrater	Fruit	Velocity of air across trays, linear feet per minute	Total volume of air, cubic feet per minute	Volume of air per 100 square feet of tray surface, cubic feet per minute	Approximate drying time, hours
F	Air-blast direct heat.......	Grapes	424	20,800	290	24
C	Air-blast direct heat.......	Grapes	485	15,800	275	24
A	Air-blast direct heat.......	Prunes	510	44,000	255	24
O	Air-blast tunnel batch type	Grapes	450	17,500	250	18–24
E	Air-blast tunnel type.....	Grapes	265	8,600	250	18–30
G	Air-blast direct heat.......	Grapes	197	7,486	235	22
B	Air-blast tunnel type.....	Prunes	357	11,390	200	30
M	Stack-type gravity air flow	Prunes	Less than 20	4,500	130	30
M	Stack-type gravity air flow	Prunes	Less than 20	4,800	100	36
N	Ceramic oven.............	Grapes	Less than 20	6,017	110	60

Velocity in Commercial Dehydraters.—In practice it has been found by observation that velocities above 300 ft. per minute and not in excess of 1,000 ft. per minute should be used in air-blast dehydraters. At velocities above 1,000 ft. per minute, static pressure and the power necessary to operate the fan become so great that additional increase in velocity is apt to become uneconomical. It is also true that evaporation from the surface of fruits and vegetables is slower than from a free surface, such as a wet lampwick, and that the Carrier equation does not apply well in high air velocities.

The velocity of air required will vary with the distance between trays and the load on the trays. A convenient way of expressing air requirements for dehydraters is in terms of cubic feet of air per minute per square foot of tray surface. For an air-blast dehydrater, this number should not be less than 250 cu. ft. per square foot of drying surface.

Measurements of air velocity and drying times for various fruits obtained in the study of dehydraters in California are given in Table 60. (Compare F and N particularly.)

Effect of Humidity and Temperature.—Tiemann in his bulletin on the theory of drying gives the relation between the temperatures and humidities of the ingoing and outgoing air, the volume of air required and the heat units required to evaporate 1 lb. of water, as shown in Table 61.

It will be seen that the efficiency H/G increases as the temperature of the entering air, t_1, and the relative humidity of the leaving air, h_3, increase.

Air Pressure.—*Static pressure* may be considered as the pressure necessary to overcome the frictional resistance offered to the flow of air. It is measured by means of a Pitot tube and is expressed in inches of water pressure.

Velocity Pressure.—Velocity pressure is that pressure required to create the velocity of air flow. *Total pressure* or *dynamic* or *impact pressure* is that pressure required to overcome frictional resistance and to create the velocity of flow, and it is the sum of the static and velocity pressures.

Pitot Tube.—This instrument consists essentially of two parts: (1) A tube pointing upstream against the flow of air, converting the sum of the static pressure and velocity pressure into a head which may be measured; and (2) a means of determining static pressure alone. For the latter measurement the Pitot tube is fitted with two small openings 0.02 in. in diameter. These openings connect with a tube which in turn is attached to an inclined manometer filled with a light liquid such as gasoline, which gives a sharp meniscus. The total pressure orifice is also connected to a similar inclined manometer by flexible rubber tubing.

TABLE 61.—RELATION OF TEMPERATURE AND HUMIDITY OF AIR TO VOLUME OF AIR AND HEAT UNITS REQUIRED TO EVAPORATE 1 LB. OF WATER
(*After Tiemann*)

Entering air		After heating		Leaving air		Heat consumed to evaporate 1 pound of water from initial temperature of 59°F.	Total heat of 1 pound of vapor at t_3 above initial temperature of 59°F.	Minimum volume of air required	Efficiency H + G
t_1	h_1	t_2	h_2	t_3	h_3				
A, °F.	B, Per cent	C, °F.	D, Per cent	E, °F.	F, Per cent	G, B.t.u.	H, B.t.u.	J, Cubic feet	K,
32	100	95	11	65.0	75	2,353	1,074	2,163	0.457
59	100	95	31	76.0	75	2,100	1,078	3,426	0.514
32	100	158	2	84.0	75	1,911	1,080	993	0.565
59	100	158	6	92.0	75	1,715	1,082	1,126	0.631
86	100	158	13	107.0	75	1,556	1,087	1,402	0.698
32	100	212	0+	97.0	75	1,758	1,084	694	0.617
59	100	212	2	103.0	75	1,572	1,086	731	0.690
86	100	212	4	114.0	75	1,422	1,089	796	0.767
32	100	95	11	84.0	25	6,136	1,080	5,738	0.176
32	100	158	2	110.0	25	2,972	1,088	1,495	0.366
86	100	158	13	141.0	25	4,869	1,098	4,385	0.225
32	100	212	0+	126.0	25	2,352	1,093	930	0.457
86	100	212	4	146.0	25	2,166	1,099	1,206	0.507
32	100	95	11	60.0	100	1,974	1,073	1,836	0.544
59	100	95	31	70.0	100	1,679	1,076	2,733	0.641
86	100	95	74	88.0	100	1,476	1,081	9,725	0.733
32	100	158	2	79.0	100	1,692	1,079	876	0.636
86	100	158	13	99.5	100	1,390	1,085	1,329	0.781
140	100	158	63	140.9	100	1,119	1,098	3,879	0.981
32	100	212	0+	90.0	100	1,582	1,082	625	0.684
86	100	212	4	106.0	100	1,350	1,087	721	0.804
176	100	212	47	176.5	100	1,130	1,108	2,002	0.972

In the above table:

t_1 = temperature F. of ingoing air.
h_1 = relative humidity of ingoing air.
t_2 = temperature of heated air.
h_2 = relative humidity of heated air.
t_3 = temperature of outgoing air.
h_3 = relative humidity of outgoing air.

The pressures are reported in inches of water, due allowance being made for the specific gravity of the liquid used in the manometer and for the inclination of the manometer.

Calculation of Air Velocity.—The difference between the total and static pressures is the velocity pressure, from which the air velocity can be calculated by the following formula:

$$V = 4{,}101\sqrt{p}$$

where p = velocity pressure in inches water gauge determined by actual test; V = velocity in feet per minute (calculated from p).

Effect of Revolutions per Minute of Fan.—The volume of air discharged by a fan varies within limits directly as the number of revolutions, and the pressures produced vary as the square of the revolutions. The power required to operate the fan varies as the cube of the revolutions. These facts explain the startling increase in horsepower required for the operation of fans when the revolutions per minute and volume of air delivered are increased by moderate amounts.

Effect of Static Pressure.—Static pressure is increased by decreasing the size of air ducts, by increasing their length, or by inserting sharp bends. Static pressure also increases with the square of the air velocity, and therefore in comparing the static pressures of any two dehydraters, the relative air velocities must be taken into account. The volume of air delivered by the fan decreases as static pressure increases. Thus, a fan which delivers 23,600 cu. ft. of air at 350 r.p.m. and 1-in. static pressure will deliver at 2-in. static pressure only 14,700 cu. ft.

Air ducts should be large so that static pressure is not excessive, and for the same reason the distance between trays should be great enough to permit unimpeded air flow. The velocity of air in return flues or passageways between the fan and the drying compartment should not exceed 1,000 ft. per minute, so that static pressure is not excessive.

The results of measurement of static pressure in several typical air-blast dehydraters in California are given in Table 62.

It is difficult to set a standard for maximum static pressure for dehydraters, but for a horizontal air-blast tunnel dehydrater 50 ft. in length and approximately 50 sq. ft. in cross section, the static pressure should not exceed 2 in. at an air velocity of 500 ft. per minute when the tunnel is filled with cars and trays of fruit.

Recirculation of the Air.—If the air used in drying fruit or vegetables is allowed to escape into the outside atmosphere after its passage through the dehydrater, a great deal of heat is lost. For example, if 10,000 cu. ft. of air per minute is used and is heated from 60 to 160°F. and in going through the dehydrater drops to 120°F., it will still be at a temperature 60°F. above that of the outside air. If the air is returned to the heating

TABLE 62.—COMPARATIVE STATIC PRESSURE IN VARIOUS DEHYDRATERS
(*After Cruess and Christie*)

Plant No.	Type of dehydrater	Static pressure in inches of water		
		At fan intake (suction)	At fan discharge (pressure)	Total static pressure
E	Air-blast tunnel with partial recirculation	......	....	0.52
E	Air-blast tunnel with total recirculation	......	....	0.56
N	Ceramic oven	−0.65	0.51	1.16
G	Air-blast tunnel, direct heat	−0.93	0.86	1.79
G	Air-blast tunnel, direct heat, no recirculation	−0.81	0.43	1.24
G	Air-blast tunnel, direct heat, complete recirculation	......	....	2.63
O	Air-suction tunnel, no recirculation	−1.63	0.07	1.70
O	Air-suction tunnel, partial recirculation	−1.76	0.13	1.89
O	Air-suction tunnel, total recirculation	......	....	2.19
P	Air-suction tunnel, tray and slide type	......	....	0.70
B	University Farm type:			
	No recirculation	−0.85	0.67	1.52
	Total recirculation	−0.16	0.74	0.90
P	No recirculation	......	....	1.28

chamber and is used again, this heat will be conserved; or conversely, if fresh air is drawn into the dehydrater to replace that discharged from it, approximately twice as much heat is required to heat the fresh air as that required to heat the spent air.

Certain fruits caseharden, *i.e.*, become overdried on the surface, and drying thereby is retarded. This condition is, to a large extent avoided if the relative humidity of the air is increased sufficiently, which can be done to a large degree by return of the spent air.

Because of these facts, it is customary in modern dehydraters to provide for recirculation of a portion or all of the air used in drying.

In the dehydraters ordinarily used in California, it is found desirable to close the air-escape damper partially and to operate the dehydraters with recirculation of most of the air in the drying of prunes, apricots, peaches, and pears, and with recirculation of about 75 per cent of the air in the dehydration of grapes, apples, sliced vegetables, and other rapidly drying materials. In the drying of walnuts most of the air is discharged without recirculation. Leakage through cracks, around doors, etc., is

sufficient to allow escape of enough air to carry from the dehydrater the moisture liberated from the fruit or vegetables.

In an experiment made by the writer at the University of California farm, it was found that recirculation of most of the air during the drying of grapes resulted in a saving in fuel of approximately 50 per cent.

Air Distribution.—Not only must the dehydrater be furnished with a sufficient volume of air, but the air so furnished must be applied to the product to be dried in an evenly distributed manner.

Frequently the space above the topmost tray on a dehydrater car is too great, and an excessively large proportion of the air flows through this space; or it may flow beneath the cars or beside them instead of between the trays.

By the placing of baffles on the walls of the dehydrater or on the cars, it is usually possible to force the air into the desired channels. Table 63 gives the results of air-flow measurements in a dehydrater before and after installation of air baffles.

TABLE 63.—EFFECT ON AIR DISTRIBUTION OF PROPER PLACING OF BAFFLES
(*After Cruess and Christie*)

Location of test	Velocity before installing baffles, feet per minute	Velocity after installing baffles, feet per minute
Velocity of air between trays near top of car	320	600
Velocity of air between trays near bottom of car	400	420
Velocity of air below cars	1,500	500
Velocity of air above top tray	2,800	500

Methods of Obtaining Air Flow.—Two means of obtaining air flow in dehydraters are in commercial use. These are by natural draft and by forced draft. In the former method the tendency for hot air to rise is used and in the second method some form of fan is employed to force the air through the dryer.

Natural-draft and forced-draft dehydraters will be discussed in greater detail later in this chapter.

Parallel- and Counter-current Systems of Drying.—In most tunnel dehydraters the fresh fruit enters at the air-exhaust end and the dried fruit leaves at the air-intake end of the drying compartment. During drying, the fruit is moved from air of moderate temperature (100 to 120°F.) at the start of drying to temperatures of 150 to 190°F. near the end of the drying period. This is termed the "counter-current" system. During the first stages very little drying occurs because of the moist condition and relatively low temperature of the air. The drying process

is completed in air of high temperature and low relative humidity, conditions that favor casehardening and scorching of the fruit.

In the so-called "parallel-current system," the fruit enters at the air-intake end of the drying compartment and is taken from the dehydrater at the air-exhaust end; the drying process is started in hot, dry air and is completed in warm, moist air. For some fruits this system possesses the following advantages:

1. Evaporation of the surplus moisture is very rapid during the initial stages of the drying period when the fruit is moist and in the best condition to give up its water.

2. The wet fruit is more nearly at the temperature of the wet-bulb thermometer because the fruit contains sufficient moisture to maintain a rapid rate of evaporation which reduces its temperature proportionately. This permits higher drying temperatures than are now used, thus still further increasing the rate of drying. In the counter-current system the fruit near the end of the drying process, because of its low moisture content and slow rate of drying, is very apt to approach the temperature of the hot, dry air and become scorched and caramelized. The parallel-current system takes fuller advantage of the drying power of air, but increases the loss of juice in the early stages of drying.

3. The fruit gradually progresses during drying toward a region of lower temperature and higher humidity, so that scorching and overdrying are minimized.

4. The fruit emerges after drying at a relatively low temperature, so that much less heat is carried to the outside atmosphere by heated cars, trays, and fruit than is the case with the counter-current system.

The counter-current has proved more satisfactory than the parallel-current system for the dehydration of prunes, while the parallel system is better adapted for the drying of halved fruits and sliced or cubed products.

Methods of Heating Air.—The air used in dehydration in commercial plants is usually heated by contact with steam pipes or with large flues heated by the products of combustion of natural gas, crude oil, wood, coal, or other fuel. It may also be heated by means of electrically heated wires or grids, or by mixing with the products of combustion of a clean-burning fuel, such as stove distillate, kerosene, or gas. All these methods are used commercially.

The method in which the products of combustion are mixed with the air used in drying is the most efficient because radiation and stack losses are reduced to a minimum.

Area of Heating Surface.—Formulas exist for the calculation of the area of the heating surface required for the heating of a given volume of

air. Expressed in the metric system, one formula is as follows (after Hausbrandt):

$$H = \frac{Cg}{tm(2 + \sqrt{c})}$$

where H = area of the heating surface in square meters; tm = mean difference in temperature between heating surface and air; c = velocity in meters per second; Cg = calories per hour.

The coefficient of heat transmission, k, varies with the square of air velocity in accordance with the following formula:

$$k = 2 + 10\sqrt{c}$$

where c = velocity of the air in meters per second.

From the first formula given above, it is also evident that heat transfer varies directly with the difference in temperature of the heating surface and the air undergoing heating.

From these considerations it would appear advisable to maintain the heating surface at a relatively high temperature and to carry the air through the heating chamber with fairly high velocity. If the air is conducted from the cooler to the warmer portions of the heating system, a larger proportion of the heat will be absorbed by the air than if it is conducted in the opposite direction.

Fuel Efficiency.—We may define fuel efficiency as that proportion of the total heating value of the fuel actually utilized in evaporating moisture from the fruit. For example, if an amount of fuel is burned sufficient to evaporate 1,000 lb. of water and if only 500 lb. of water are evaporated, the fuel efficiency is 500/1,000, or 50 per cent.

Since approximately 1000 B.t.u. of heat are required to evaporate 1 lb. of water and since 1 gal. of fuel oil will furnish approximately 142000 B.t.u., a simple formula for calculating the efficiency of a given dehydrater is the following:

$$\frac{\text{Pounds fresh fruit} - \text{pounds dry fruit}}{\text{Gallons of oil consumed} \times 142} = \text{fuel efficiency}$$

Data were collected upon a number of dehydraters in California, and their efficiencies were calculated by means of the above formula, with the results shown in Table 64.

A well-designed dehydrater should have a fuel efficiency, calculated by the above formula, of at least 40 per cent in drying prunes or grapes, but an efficiency above 50 per cent is very difficult to attain under usual conditions.

TABLE 64.—COMPARATIVE FUEL EFFICIENCIES OF SEVERAL TYPES OF DEHYDRATERS
(*After Cruess and Christie, Bull.* 337)

Plant No.	Type of dehydrater	Fruit dried	Fuel efficiency, per cent
E	Air-blast tunnel indirect heat	Apricots	58
N	Ceramic oven	Apples	50
F	Air-blast tunnel direct heat	Grapes	48
N	Ceramic oven	Grapes	44
E	Air-blast tunnel indirect heat	Peaches	43
E	Air-blast tunnel indirect heat	Pears	43
B	Air-blast tunnel indirect heat	Prunes	42
J	Air-blast tunnel	Prunes	39
J	Air-blast tunnel (same design as preceding but in another location)	Prunes	38
E	Air-blast tunnel indirect heat	Grapes	38
H	Air-blast cabinet	Prunes	30
M	Stack-type gravity air flow	Prunes	24
M	Small stack-type gravity air flow	Apricots	14

Effect of Temperature of Air on Drying Rate and Efficiency.—The capacity of air to take up moisture rapidly increases with rise of temperature and the amount of heat necessary to evaporate a given weight of water decreases with rise in temperature (see Table 45).

Critical Temperature.—The temperature of the air used in dehydration greatly affects, not only the time required for drying, but also the quality of the finished product. In order to secure large capacity and minimum operating costs, it is necessary to use the highest temperature that will not materially injure the product. Most dehydraters which involve a progressive movement of the fruit through the drying chamber have used the counter-current system. The "critical temperature" for any fruit is the temperature at which, when the fruit is almost dry, it may undergo undesirable changes in color or flavor. In the counter-current system this temperature is the maximum which can be used, while in the parallel-current system this temperature must not be exceeded in the final stages of drying, although much higher temperatures can be used while the fruit still contains an excess of moisture.

The maximum advisable finishing temperatures for each of the more important fruits are given in Table 73.

Experiments by Gadgil, Winkler, and Bjarnason, graduate students in the University of California, indicated rapid loss of sugar when raisins were heated to 185°F. after becoming nearly dry. At lower temperatures, the effects were negligible unless the raisins were allowed to become

very much overdried, a condition which should never occur in a commercial plant. The extent of such sugar loss is indicated in Table 65.

TABLE 65.—LOSS OF SUGAR FROM RAISINS SUBJECTED TO VARIOUS TEMPERATURES

Temperature, °F.	Hours exposed	Per cent of sugar loss
140	8	0.6
140	16	0.8
140	32	1.0
167	8	1.3
167	16	1.9
167	32	6.2
185	8	8.7
185	16	12.2
185	32	14.9

Relative Humidity.—Relative humidity of air may be defined as its percentage of saturation with moisture vapor. Air completely saturated with water vapor at a given temperature is at 100 per cent relative humidity; air at the same temperature containing one-half the amount of water vapor that it is capable of absorbing is at 50 per cent relative humidity. The absolute amount of water vapor that air can absorb (within certain temperature limits) approximately doubles with each 27°F. rise in temperature.

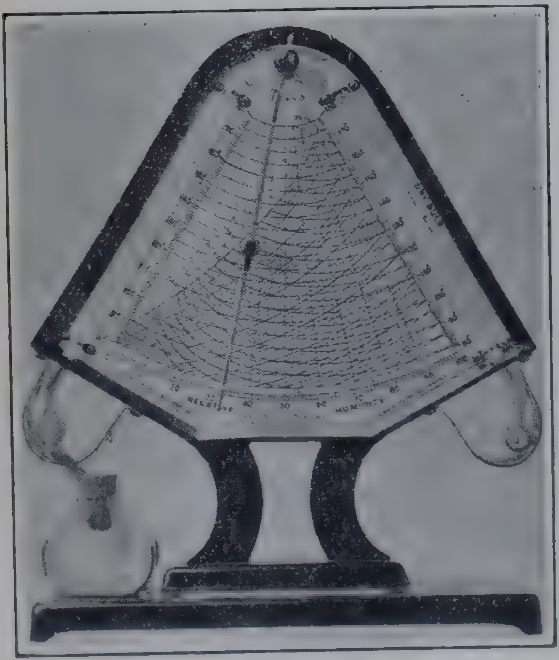

FIG. 80.—Wet- and dry-bulb thermometers of type commonly used for determination of relative humidity in dehydraters.

Casehardening.—Large pieces of fruit, such as halved pears, peaches, or whole Imperial prunes, caseharden if the relative humidity is so low and the temperature so high that the moisture is removed more rapidly from the surface than it diffuses from the interior of the fruit. Casehardening (searing over of the surface) retards the rate of evaporation because it impedes the diffusion of water to the surface of the fruit.

In drying pears and peaches it has been found that casehardening was materially reduced by increasing the relative humidity of the air at 150°F. to 30 to 35 per cent.

Thinly sliced fruits (*e.g.*, pears, apricots, and peaches), dipped grapes, small- to medium-size prunes, and dipped cherries do not caseharden seriously.

Dew Point.—Relative humidity may also be defined as the ratio of the vapor pressure of the water vapor present in a given space to the vapor pressure of water vapor in that same space saturated with water vapor. The saturation point is ordinarily known as the dew point (*i.e.*, 100 per cent relative humidity).

Determination of Relative Humidity.—Relative humidity is determined by comparison of the temperature of wet- and dry-bulb thermometers. Evaporation of moisture from the wet-bulb thermometer causes a drop

TABLE 66.—RELATION OF HUMIDITY TO DIFFERENCE IN TEMPERATURE OF WET- AND DRY-BULB THERMOMETERS

(*After The Foxboro Company, Inc., Foxboro, Mass., catalogue* 101-1, *p.* 9)

Dry bulb, deg. F.	Difference between readings of wet and dry bulbs in degrees F.																																			Dry bulb, deg. F.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	22	24	26	28	30	32	34	36	38	40	45	50	55	60	65	70	
70	95	90	86	81	77	72	68	64	59	55	51	48	44	40	36	33	29	25	22	19	12	6	0	0													70
75	96	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34	30	27	24	18	12	7	1	0												75
80	96	91	87	83	79	75	72	68	64	61	57	54	50	47	44	41	38	35	32	29	23	18	12	7	3	0											80
85	96	92	88	84	80	76	73	70	66	63	59	56	53	50	47	44	41	38	35	32	27	22	17	13	8	4	0	0									85
90	96	92	89	85	81	78	74	71	68	65	61	58	55	52	49	47	44	41	39	36	31	26	22	17	13	9	5	1	0								90
95	96	93	89	85	82	79	75	72	69	66	63	60	57	54	52	49	46	43	42	38	34	30	25	21	17	13	9	6	2	0							95
100	96	93	89	86	83	80	77	73	70	68	65	62	59	56	54	51	49	46	44	41	37	33	28	24	21	17	13	10	7	4	0						100
105	97	93	90	87	83	80	77	74	72	69	66	63	60	58	55	53	50	48	46	44	40	36	32	28	23	20	16	13	11	8	0						105
110	97	93	90	87	84	81	78	75	73	70	67	65	62	60	57	55	52	50	48	46	42	38	34	30	26	23	20	17	14	11	4	0					110
115	97	94	91	88	85	82	79	76	74	71	68	66	63	61	58	57	54	52	50	48	43	40	36	32	28	26	22	20	16	14	7	2	0				115
120	97	94	91	88	85	82	80	77	74	72	69	67	65	62	60	58	55	53	51	49	45	41	38	34	31	28	25	22	19	17	10	5	0				120
125	97	94	91	88	85	83	80	78	75	73	70	68	66	63	61	59	57	54	52	50	47	43	40	36	33	30	27	24	22	19	13	7	2	0			125
130	97	94	91	89	86	83	81	78	76	73	71	69	67	64	62	60	58	56	54	52	48	45	41	38	35	32	29	26	24	21	15	10	6	1	0		130
135	97	94	92	89	86	84	81	79	76	74	72	69	67	65	63	61	59	57	55	53	50	46	43	40	36	34	30	28	26	23	18	12	8	3	0		135
140	97	95	92	89	87	84	82	79	77	75	73	70	68	66	64	62	60	58	56	54	51	47	44	41	38	35	32	30	27	25	19	14	10	5	2		140
145	98	95	93	90	87	84	82	80	78	75	73	71	69	67	65	63	61	59	57	55	52	48	45	42	39	36	34	31	29	27	21	16	12	7	4	0	145
150	98	95	93	90	87	85	82	80	78	76	73	71	70	68	65	64	62	60	58	56	53	49	46	43	41	38	35	33	30	28	23	18	13	9	5	2	150
155	98	95	93	90	87	85	83	81	79	76	74	72	70	68	66	64	63	61	59	57	54	50	47	44	42	39	37	34	32	30	24	19	15	11	7	4	155
160	98	95	93	90	88	85	83	81	79	77	75	73	71	69	67	65	63	62	60	58	55	51	48	46	43	40	38	35	33	31	25	21	16	12	9	6	160
165	98	95	93	91	88	86	84	82	80	78	75	73	72	70	68	66	64	62	61	59	56	52	49	47	44	41	39	37	34	32	27	22	18	14	10	7	165
170	98	96	94	91	89	86	84	82	80	78	76	74	72	70	69	67	65	63	62	60	57	53	50	48	45	42	40	38	35	33	28	23	19	15	12	9	170
175	98	96	94	91	89	86	84	82	81	79	76	74	73	71	69	67	66	64	62	61	58	54	51	49	46	43	41	39	36	34	29	25	20	17	13	10	175
180	98	96	94	92	89	87	85	83	81	79	77	75	73	72	70	68	66	64	63	61	58	55	52	50	47	44	42	40	37	35	30	26	21	18	14	12	180
185	98	96	94	92	89	87	85	83	81	80	77	76	74	72	70	69	67	65	64	62	59	56	53	50	48	45	43	41	38	36	31	27	22	19	16	13	185
190	98	96	94	92	90	87	85	83	82	80	78	76	74	73	71	69	68	66	64	63	60	57	54	51	49	46	44	42	39	37	32	28	24	20	17	14	190

in temperature in proportion to the rate of evaporation, which is dependent upon the relative humidity of the air. Table 66 published by the Foxboro Instrument Company, gives the relation between wet bulb, dry

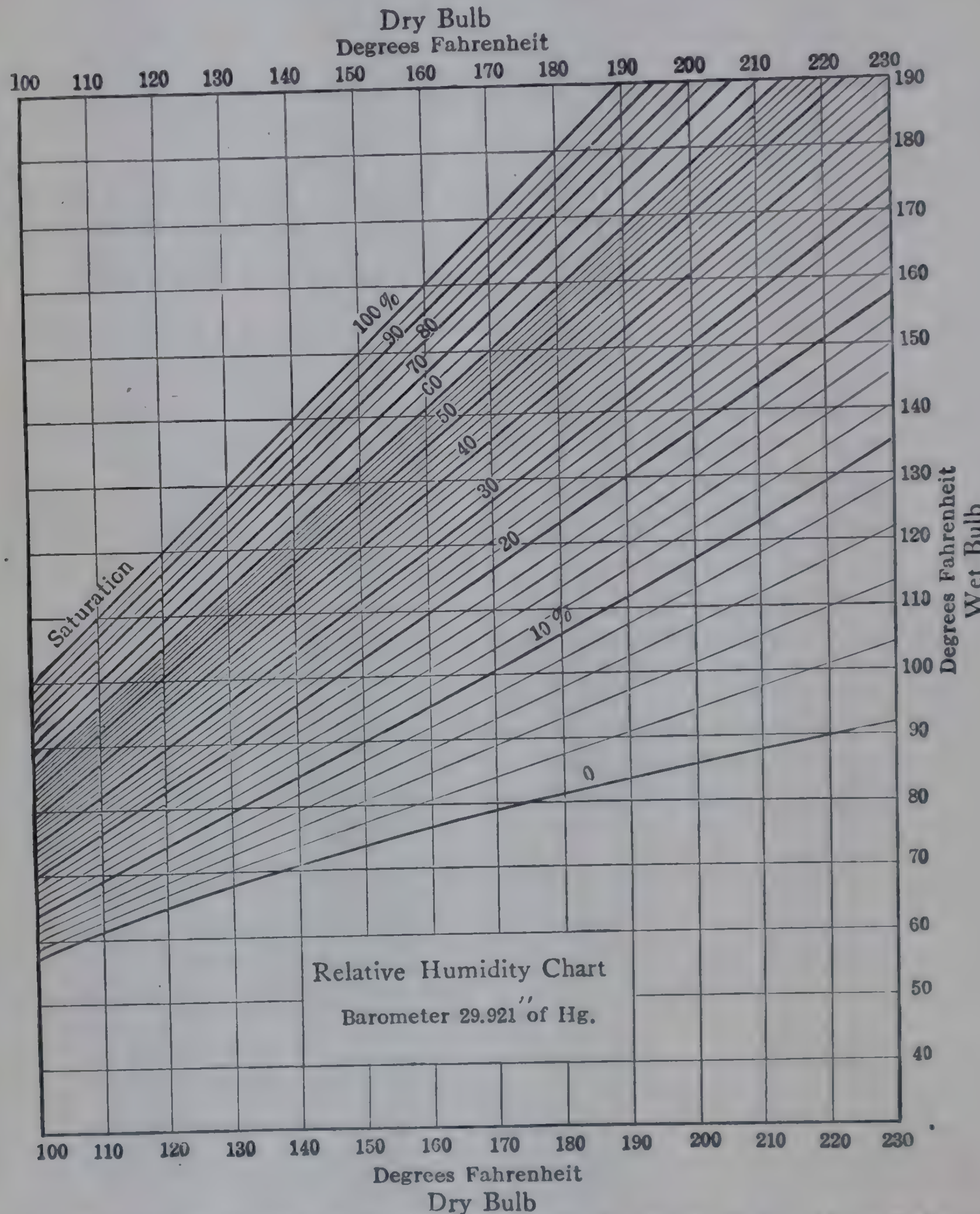

FIG. 81.—Relative humidity chart (prepared by G. B. Ridley, S. F. (*After Bulletin* 337, *Univ. of Calif. Exp't. Sta., by Cruess and Christie.*)

bulb, and relative humidity for temperatures commonly met with in the dehydration of fruits.

In using the table, in the topmost horizontal row find the difference in temperature nearest that of the observed *difference* in temperature between the wet-, and dry-bulb thermometers. Follow down the vertical column directly beneath this difference in temperature until this vertical

column cuts the horizontal row opposite the dry-bulb thermometer temperature. The figure at the point of intersection is the relative humidity. An example will make this explanation clearer:

Dry-bulb reading, 130°F.; wet-bulb reading, 103°F.; difference, 27°F. In Table 66, 28° is the nearest temperature given. Follow down 28°F. column until the horizontal row opposite 130°F. is met. At this point of intersection will be found 38, the approximate per cent relative humidity. More accurate results are obtainable by interpolation or by use of the chart shown in Fig. 81.

Humidity Chart.—In Fig. 81 is shown a relative humidity chart prepared by G. B. Ridley. The chart is self-explanatory and, if drawn to a large scale, is more convenient than tables.

Vapor Pressure.—The pressure causing water to evaporate is vapor pressure. The vapor pressure of partially saturated air may be calculated by various formulas from wet- and dry-bulb readings (Carrier).

Temperature of Product.—It is reasonable to suppose that, as long as the evaporation is not forced beyond the ability of the material undergoing drying to part with its free water, its temperature will be essentially that of the wet-bulb thermometer and its vapor pressure will be that of the saturated vapor at that temperature. When the attempted rate of evaporation is greater than that at which the material can give up its moisture, the temperature of the material will rise above that of the wet-bulb thermometer, and the condition will be like that of an autoclave from which the rate of flow is controlled by a cock.

Heat Losses.—The greatest heat loss in dehydration is that in the exhaust air. Under some conditions this may amount to 50 per cent of the total heat generated in the furnace and is frequently more than 25 per cent of this total. By recirculation of the air this loss can be greatly reduced but not entirely eliminated under practical working conditions.

Leakage of air through cracks or around doorsills, etc., and radiation of heat from the walls may also become serious causes of heat losses.

Considerable heat is lost in the gases from the stack of the furnace or boiler. With a properly designed and operated furnace and radiating-pipe type of heating apparatus, the temperature of the flue gases at the outlet of the stack should not be above 200°F.

TYPES OF DEHYDRATERS

There are many forms of dehydraters in commercial use and many others which have been designed by various inventors and have been patented but not used commercially. In many cases dehydraters have been designed and built but have failed to perform satisfactorily because the fundamental principles of dehydration were not understood or considered.

A satisfactory dehydrater should permit of close control of temperature, air velocity, and relative humidity.

Because of space limitation it is impossible to give in this book complete plans and specifications for even the more important types of driers. A brief description only of the more important features of dehydrater types in commercial use will be given. A list of bulletins of state Experiment Stations and of the U. S. Department of Agriculture and other publications, some of which give working specifications for various evaporators and dehydraters, will be found at the end of this chapter.

In general, we may place driers in three classes, *viz.:* (1) natural-draft driers; (2) forced-draft driers; and (3) distillation driers, including those operating under vacuum.

Natural-draft Driers.—Most of the driers used in New York State and California for the drying of apples and hops and in Oregon and Washington for the drying of fruits are of the natural-draft type, which

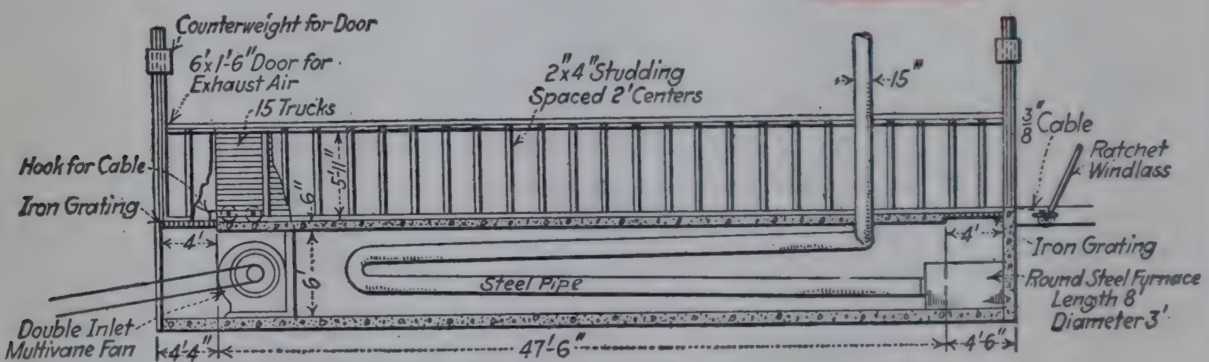

FIG. 82.—Recirculating air-blast dehydrater. (*After Wiegand.*)

requires no fan. They possess the advantages of simplicity of construction and operation and, although inefficient in their use of fuel, are relatively inexpensive to build.

Natural-draft driers, in general, consist of a furnace room or steam pipes surmounted by a drying chamber. Cold air enters the furnace room near the ground level, is heated by contact with the furnace radiating pipes or steam coils and rises through the drying compartment, where it comes in contact with the fruit or other product undergoing drying.

Kiln Drier.—The kiln drier, one of the oldest types still in commercial use for the drying of apples and hops, is constructed in two stories. The upper story houses the drying floor, which is usually about 20 ft. square and made up of strips of hardwood 1/4 in. apart. Over the floor is a steep four-sided roof, equipped at the apex with a large ventilator for the escape of spent air. The prepared fruit or other product is placed directly on the floor in a layer 3 to 12 in. in depth and is stirred with a fork or scoop shovel during drying.

The furnace room houses a large wood-, coal-, or oil-burning furnace connected to a series of large sheet-metal pipes which are led around the

furnace room several times before joining the stack. In some cases the furnace and radiating pipes are replaced with a steam boiler and steam pipes, the latter placed immediately beneath the drying floor. While more expensive to install, the steam-heated kiln permits of more careful regulation of the temperature and makes possible the use of higher temperatures than is feasible with the usual pipe and former type of kiln. Drying rate can be increased by installing a fan in the ventilating duct.

The kiln drier is satisfactory for hops and gives fairly satisfactory results in the drying of apples but is unsuited to the drying of soft fruits, such as prunes, grapes, peaches, etc., because of bruising (for details of construction see Caldwell).

Tower Drier.—The "tower" or "stack" drier consists of a furnace room about 10 ft. in height, in which are located a furnace and heating pipes of the same general design as the heating system used for the Oregon tunnel drier and of cabinets in which trays of fruit are dried. Each stack or cabinet holds about 12 trays, usually 3 ft. square in size and each furnace room usually accommodates six stacks of trays. The heated air from the furnace rises through the trays.

In operating this drier the cabinets are filled with trays of the fresh fruit, and as the trays at the bottoms of the stacks become dry, they are removed and are replaced with freshly loaded trays, which are entered on the topmost tray runways. Each time a fresh tray enters the stack the whole set of trays is shifted downward one tray.

Cabinet Drier.—This dryer is similar in design and in operation to the stack drier, but heat for drying is furnished by steam coils placed between the trays. Drying is rapid, and the temperature can be very conveniently and exactly regulated. It is a very great improvement over the old stack drier (for details of construction see Beattie).

Oregon Tunnel Drier.—This is the most common drier in use in the Pacific northwest. It was invented by Allen about 50 years ago and is often known by his name.

In a general way, it may be described as a series of parallel, sloping narrow chambers above a furnace room. The trays of fruit enter the drier at the upper or cooler end on runways and progress toward the lower or warmer end. The dry fruit is removed from the lower end of each tunnel. The furnace room is similar in design to that used for the kiln drier, and the drying tunnels rest on a floor about 12 to 16 ft. above the floor of the furnace room, which serves two to four tunnels. Each tunnel is about 20 ft. long by about 5 ft. in height by about 3 ft. in width and slopes approximately 2 in. per foot. At one time tunnels were much longer than 20 ft., but more rapid and uniform drying is obtained by the shorter tunnels. Hot air enters the lower end of each tunnel through an opening or "throat" approximately 3 ft. in width,

which is fitted with a sliding door by means of which the amount of air passing through the drier can be regulated. Figure 83 illustrates the main features of an Oregon tunnel drier.

In recent years many owners of tunnel driers have installed fans by means of which most of the air is recirculated and the efficiency of the tunnels greatly increased.

There is a considerable difference in the temperature of air at the upper and lower ends of the tunnel, a fact which renders the tunnel drier more efficient in its use of fuel and heat than tower or kiln driers, but nevertheless the Oregon tunnel is less efficient than air-blast driers. The temperature at the upper end of the tunnel is usually 30 to 50°F. lower than at the furnace end, and on this account the tunnel drier is especially well adapted to the drying of prunes, since overheating, bursting, and dripping of the fresh fruit are lessened.

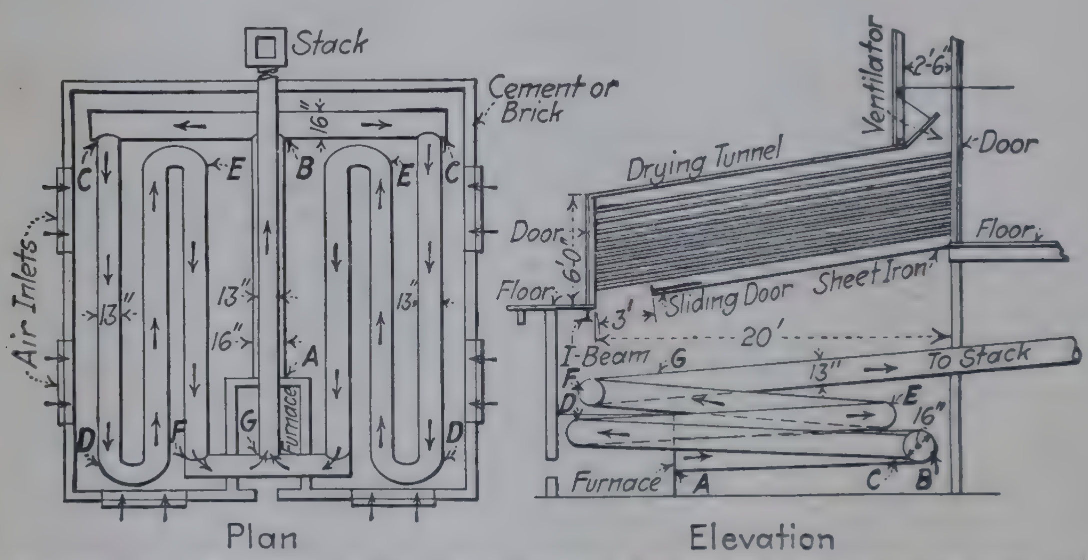

FIG. 83.—Sketch of Oregon tunnel drier showing arrangement of heating pipes. (*After Lewis.*)

Ceramic Oven.—Driers built on a design similar to that of a bake oven have been built in California. The walls are of heavy masonry and firebrick, and heat is radiated from the walls, ceiling, and floor to the fruit, which is held on trays on trucks. Owing to uneven and slow drying of the fruit occasioned by inadequate air flow, this drier was later equipped with forced draft and a recirculation system which notably improved the rate of drying. It is, however, no longer being built in California.

Distillation Type at Atmospheric Pressure.—In this type of drier the moisture is driven from the product by heat, and the water vapor so evolved is condensed by water-cooled coils or by sprays of cold water. This principle has not been applied commercially to the drying of fruits, although it is used in lumber kilns.

Vacuum Dehydraters.—Vacuum dehydraters are in use for the drying of some chemicals and other manufactured products which are easily

injured by high temperatures and oxidation. Drying *in vacuo* permits the use of low temperatures of drying and minimizes oxidation, but the equipment needed is rather complicated and expensive and for these reasons has not found general application in the drying of fruits and vegetables.

In its commercial form, the vacuum dehydrater consists of a heavy-walled sheet-metal or cast-iron chamber fitted with steam-heated shelves or coils on which rest trays of the material to be dried. The chamber is connected with a vacuum pump and spray or coil condenser for maintaining a high vacuum and for condensing moisture liberated in the drying compartment.

Dehydration in a vacuum requires less heat than in a drier operating with heated air because most of the heat supplied to the vacuum drier is used in the evaporation of moisture.

Since it reduces the tendency for fruits to darken, possibly the vacuum method of dehydration may be employed as a means of reducing the length of sulfuring of fruit before dehydration, or in some cases of completely eliminating sulfuring. It is used by one Californian producer for drying previously dried fruits to a bone-dry condition in order that this may be ground to a powder.

Forced-draft Tunnel Dehydrater.—The forced-draft tunnel dehydrater has proved to be the most efficient type of drier in commercial use in California for the drying of fruits. It also permits of most rapid drying without injury, is the least costly dehydrater to build and to operate, and permits of more uniform drying. It normally consists of a chamber longer than wide, through which the product to be dried moves progressively on trays. The drying chamber or tunnel is supplied with a current of heated air which is introduced at one end and removed from the opposite end.

Methods of Heating the Air.—The air used in forced-draft driers is heated in one of four ways: by steam coils, by electrically heated grids, hot-air furnaces, or by mixing with the products of combustion from the furnace. Electric heating is the most expensive method to install and operate but allows exact regulation.

Hot-air furnaces and heating systems have been described for the kiln drier. Similar systems are in use for heating air in forced-draft driers of all types. In using electricity for heating, the air is passed over grids of resistance wire heated by passage of electric current. It is used only for high priced products such as candied fruits and to some extent walnuts.

Direct heating of the air by mixing it with the products of combustion has been used successfully in several dehydraters. Fuel is burned in a furnace in which is built a checkerwork of firebrick, which breaks up the flame and favors complete combustion. The products of combustion are mixed with cold outside air or that returned from the drying chamber,

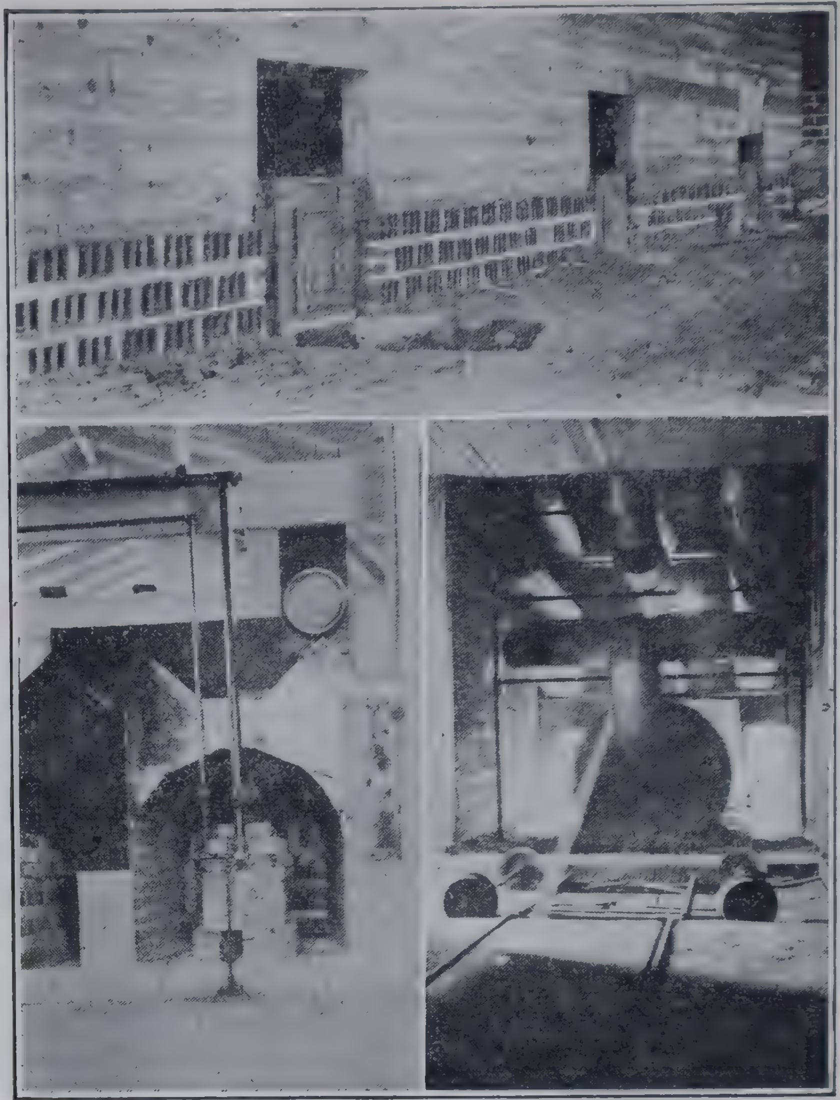

FIG. 84.—Upper: Air intakes and furnace doors of Oregon tunnel drier. Lower right: Indirect air-heating system. Lower left: Direct air-heating furnace.

FIG. 85.—Some types of dehydrater cars.

and the mixed gases are drawn through the fan and forced into the tunnel. The thermal efficiency of this system is greater than either the steam heating or hot-air furnace systems. Figure 84 illustrates the direct and indirect air-heating systems.

. It requires a special grade of fuel, *viz.*, gas, stove distillate, engine distillate, or kerosene. In the drying of white fruits there is danger of blackening the fruit from the formation of soot in the furnace through incomplete combustion caused by clogging of the burners or temporary stopping of the motor operating the air line for the burners.

Fans.—The heated air is either forced through the tunnel under positive pressure by means of a blower fan or is drawn through the tunnel by means of a suction fan. Both are satisfactory. Where a suction fan is used, the tunnel should be equipped with air locks at each end so that the cars of trays may enter and be removed from the tunnel without excessive reduction in temperature.

Fans are of four types: disk, multivane, aeroplane propeller, and paddle wheel. Under most conditions the multivane type of fan is to be preferred to the disk fan. The disk fan resembles a windmill in appearance and is cheap but will not deliver air against appreciable static pressure. Figures 88 and 89 illustrate the two types. The paddle-wheel fan is similar in principle to the multivane but has fewer vanes. It is thoroughly satisfactory. The airplane-propeller type fan is also quite satisfactory and its use in dehydration is increasing.

Relative Position of Furnace and Tunnel.—The furnace room may be located at one end of the tunnel, at the side, or above or below the tunnel. It is advisable that it be so placed that the cars or trays may enter one end of the tunnel and be removed from the opposite end without the necessity of transferring to separate cars. A very convenient arrangement is that in which the furnace and heating systems are located in a tunnel beside the drying tunnel, with the fan located in the furnace room. Air is delivered to the drying tunnel by a duct beneath the floor or in the wall of the drying tunnel. No air locks or transfer systems are required under these conditions.

Cars.—The material to be dried is usually spread on trays which are either carried through the tunnel on cars or on runways, as in the Oregon tunnel drier. The car system is the one more generally used. The cars operate on tracks in most cases, but they may be equipped with caster wheels to permit moving to any part of a concrete floor in the preparation room or drier, or they may be carried by an overhead conveyer.

In small tunnels the cars are moved by hand; in large plants they are drawn by a winch or by other power (see Fig. 85).

Recirculation.—It is desirable that the forced-draft tunnel dehydrater be so constructed that any proportion of the air may be recircu-

lated. The return-air duct must be large enough to permit unimpeded flow of the air, in order that static pressure shall not be excessive. The position of the return flue is optional, as it may be above, below, or at one side of the tunnel. The furnace room may be so placed that it serves as a return flue.

FIG. 86.—Common types of dehydrater trays.

FIG. 87.—Types of dehydraters in California. Upper: Modern four-tunnel air-blast dehydrater. Lower: Obsolete natural-draft-stack evaporator.

Other Types of Forced-draft Dehydraters.—The stack drier and Oregon tunnel driers have, in some instances, been equipped with a fan to improve air circulation. The results obtained have more than compensated for the cost of such installations.

Continuous draper or belt tunnel driers are in use for the drying of vegetables, starch, soap chips, etc. The drier consists of a tunnel with

several woven metal-cloth endless conveyers placed one above the other. Air heated by steam coils is in one type blown lengthwise of the tunnel by a single large fan and in another type is blown across the trays at right angles to the greater diameter of the tunnel by several fans placed at the side of the drying compartment. One serious objection to the

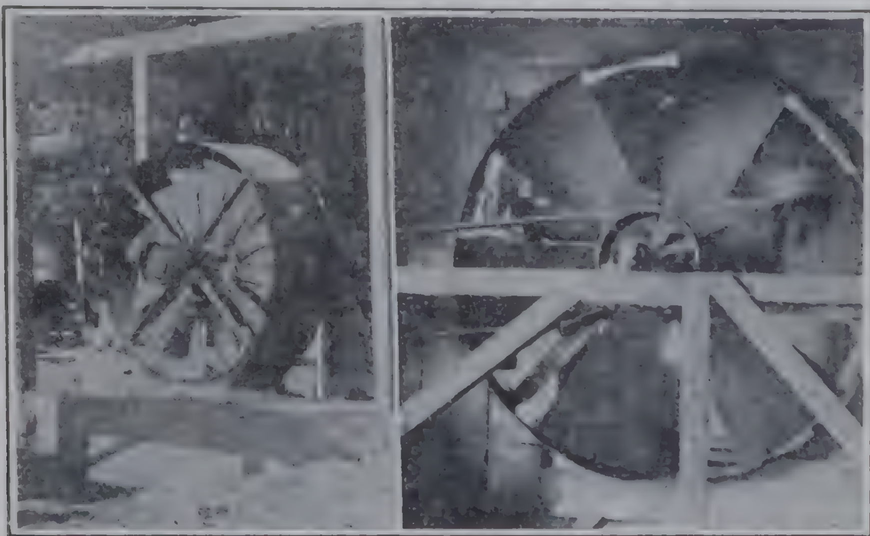

Fig. 88.—Disk fans. At left: Commercially built fan. At right: Home-made fan.

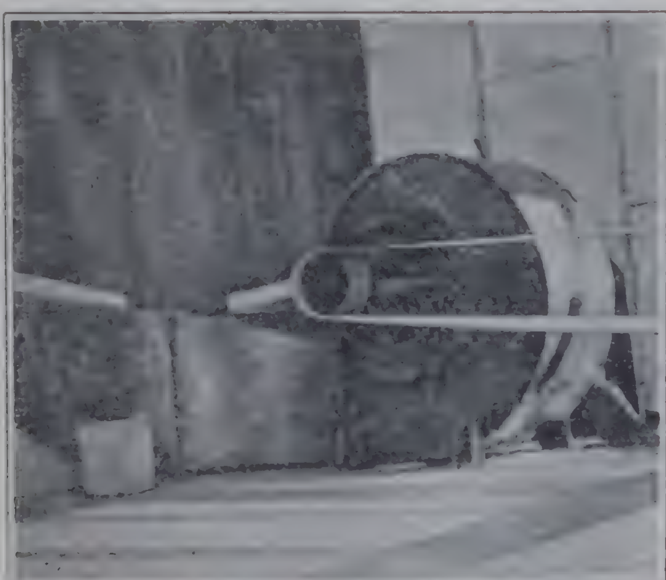

Fig. 89.—Multivane fan attached to dehydrater.

draper drier is that the drying area is much less than in a dehydrater of equal volume using trays.

Air-blast cabinet driers are in use in which the trays are placed on runways in cabinets. Air is delivered between each pair of trays by a small duct or "tuyere," and the direction of flow is reversed frequently to insure uniform drying at all points on the trays. This drier is unnecessarily complicated.

In other cases the air is forced upward through the trays, but resistance to air flow is so great that drying is slow and uneven.

Trays.—Dehydrater trays vary greatly in size, design, and in materials of construction. Three types are shown in Fig. 86.

Screen Trays.—The most common tray used in the tower and Oregon tunnel driers is made of a wooden frame and galvanized-iron wire screen. The size of the trays is usually 3 by 3 ft. or 3 by 4 ft. These trays are satisfactory for unsulfured fruits, but the zinc coating rapidly corrodes in sulfur fumes, the fruit absorbs zinc salts and acquires a metallic taste. With continued use, the zinc is completely removed and the iron is exposed. This dissolves in fruit juices and reacts with the tannin of fruits to give iron tannate, causing the fruit to blacken where it comes in contact with the screen. No satisfactory coating has been found for such trays.

Slat Trays.—The most satisfactory tray for general use is the slat bottom tray, about 3 by 3 ft. in size. It may consist of narrow wooden strips attached to a wooden frame with sides of 1½- by 3-in. material and ends of 1- by 2-in. pieces, when used on trucks in forced-draft dehydraters. The height of the sides may be greater or less than that given above and the size of the trays larger or smaller, as desired.

Solid wooden-bottomed sun-drying trays are sometimes used in driers, particularly following early fall rains, in salvaging rain-damaged fruit. When such trays are used, wooden strips must be placed between the ends to provide space for passage of the air. Drying is slower than on screen trays.

Trays 6 by 3 or 8 by 3 ft. in size are not satisfactory where the air flows across the greater length of the tray, because the fruit on the end of the tray nearest the source of heat dries more rapidly than fruit at the opposite end; or if the direction of air flow is reversed frequently, the fruit near the middle of the tray dries more slowly than at the two ends.

Tray Capacity.—At the University of California dehydrater at Davis, trays held 2 lb. of medium-size halved apricots per square foot, 3 lb. of medium-sized halved Muir peaches, 3 lb. of halved pears, 2½ to 3½ lb. of prunes one layer deep and 3 to 4 lb. of grapes. Sliced or cubed apples and cubed vegetables are loaded on trays at the rate of about 2 lb. per square foot.

Plant Investment.—For the average fruit grower the plant investment should be as low as is compatible with reasonable efficiency, because the duration of the fruit season is so short that it causes the overhead cost of plant investment to be excessive unless the construction cost is low.

Cost per Ton Capacity.—A survey of dehydraters in California showed that it was possible to erect an efficient and satisfactory dehydrater for approximately $500 per green ton of fruit dried per 24 hr. The cost of buildings and accessory equipment is additional. The relation of plant

investment to drying costs for several typical driers in California is shown in Table 67.

TABLE 67.—COST OF DEHYDRATION AS AFFECTED BY PLANT INVESTMENT
(*After Cruess and Christie*)

Plant No. †	Type of plant	Capacity, green tons per 24 hours	Total first cost of plant	Cost of plant per green tons, 24 hours	Fixed charges per green ton on basis of 60-day season*					Total per dry ton
					Interest	Depreciation	Insurance	Taxes	Total	
A	Air-blast tunnel, direct heat	25.0	$12,000	$ 480	$0.56	$0.80	$0.10	$0.24	$1.70	$ 5.10
E	Air-blast tunnel indirect heat	6.0	4,000	667	0.78	1.11	0.14	0.29	2.32	6.96
F	Air-blast tunnel, direct heat	35.0	25,000	715	0.83	1.19	0.15	0.32	2.49	7.47
H	Air-blast cabinet	12.0	15,000	1,250	1.46	2.09	0.26	0.55	4.36	13.08
K	Small stack-type	0.75	1,500	2,000	2.33	3.55	0.42	0.89	7.19	21.57
L	Air-blast stack-type	1.50	4,000	2,666	3.11	4.44	0.55	1.48	9.28	27.84
M	Stack-type, large size	9.0	25,000	2,778	3.24	4.63	0.58	1.23	9.68	28.04
N	Ceramic oven	6.0	25,000	4,167	4.17	6.94	0.87	1.39	13.37	40.01

* Interest at 7 per cent; depreciation at 10 per cent; insurance at 2½ per cent of ½ value; taxes at 4 per cent of ⅔ value.

† These letters are used to designate the same dehydraters in other tables.

In the table, for comparative purposes, a drying season of 60 days was assumed; 30 days for drying grapes; and the same length of time for prunes. A drying ratio of 3.5:1 was assumed for grapes and 2.5:1 for prunes or an average ratio of 3:1.

Cost of Operation.—The cost of dehydrating prunes and grapes in several California dehydraters is shown in Table 68. For comparative

TABLE 68.—COMPARATIVE COSTS OF DEHYDRATION
(*After Cruess and Christie*)

Plant No.	Type	Fruit	Cost per green ton					
			Labor	Fuel	Power and light	Total operating charges	Fixed charges, from Table 66	Total cost of production
D	Air-blast tunnel, direct heat	Prunes	$3.19	$0.94	$0.48	$4.61	$2.07	$6.68
E	Air-blast tunnel indirect heat	Grapes	4.16	2.05	0.45	6.66	2.32	8.98
H	Air-blast cabinet	Prunes	4.80	1.63	0.55	6.98	4.36	11.34
N	Ceramic oven	Grapes	4.56	1.44	0.59	6.59	13.37	19.96
M	Stack-type gravity air flow	Prunes	9.75	3.26	0.20	13.21	9.68	22.89

purposes uniform costs of 6 cents per gallon for fuel, 2½ cents per kilowatt hour for power, and 50 cents per hour for labor were used.

Natural-draft driers showed a higher operating cost than forced-draft driers (compare driers D and M in Table 68).

Moisture Content of Dried Fruits.—The U. S. Department of Agriculture has placed the legal limit for moisture in dried apples at 24 per cent. It is likely that similar standards will in time be adopted for all dried fruits. In order to have a careful check on the moisture content, it is highly desirable for every plant to make frequent moisture determinations on representative samples (see Cruess and Christie's "Laboratory Manual of Fruit and Vegetable Products" for methods of analysis).

Experiments have proved that most fruits containing not more than 23 per cent of moisture will keep indefinitely. Unsulfured fruits containing 24 to 30 per cent of moisture sooner or later become moldy, while those above 30 per cent soon ferment unless heavily sulfured to prevent spoiling. These limits do not hold for sulfured fruits because of the preservative action of the sulfur dioxide.

Prunes containing more than 26 per cent of moisture in most instances become moldy.

Fireproof Construction.—The fire risk with most dehydraters built of wood is very hazardous, and insurance rates on such structures are high. On this account most of the dehydraters built in California in recent years have been constructed of hollow tile, concrete, or other fireproof material. Insurance may then be dispensed with, except for trays and cars.

The greater original cost of fireproof driers is compensated for within a few years by the saving in insurance cost and lower depreciation.

DEHYDRATION OF FRUITS

Dehydration affords a means of producing dried fruits of new forms and, in some instances, of better quality than is possible by sun drying. Practically all fruits can be successfully dehydrated, although some of these fruits do not yield acceptable products by sun drying.

Preparation.—Preparation of fruits for dehydration is similar to that for sun drying. A brief outline of approved methods of preparing some of the more important fruits is given below. The loss in preparing various fruits for dehydration is given in Table 69 (see also Tables 70 and 73).

Comparative Yields and Qualities of Sun-dried and Dehydrated Fruits.—Accurately controlled comparisons of sun drying and dehydration of apricots, peaches, pears, and prunes were made at the University of California. Fruit of the same condition was used for the two methods of drying, and any subsequent differences in the dried product were a direct result of the method of drying.

TABLE 69.—SHRINKAGE IN THE PREPARATION AND DEHYDRATION OF VARIOUS FRUITS
(*After Cruess and Christie*)

Fruit	Per cent of fresh fruit unsorted					Drying ratio	
	Sorted uncut fruit	Prepared fruit cut, pitted, dipped or hulled	Prepared and peeled fruit	Loss in preparation	Dried fruit	Gross fresh to net dry	Prepared fresh to net dry
Royal apricots	100.0	92.3	.....	7.7	17.2	5.8:1	5.4:1
Muir peaches, unpeeled	96.4	90.3	.....	9.7	20.9	4.8:1	4.3:1
Muir peaches, lye peeled	96.4	90.3	86.2	13.8	19.9	5.0:1	4.3:1
Bartlett pears	97.9	91.7	.....	8.3	19.5	5.1:1	4.7:1
Bartlett pears, peeled	97.9	91.7	60.5	39.5	12.9	7.8:1	4.7:1
Grapes	100.0	100.0	100.0	....	27.5	3.6:1	
Newton apples	100.0	.....	75.0	25.0	12.3	8.3:1	6.1:1
Loganberries	100.0	100.0	100.0	....	21.1	4.7:1	4.7:1
Cherries, not pitted	100.0	100.0	100.0	....	33.5	3.0:1	3.0:1
Cherries pitted and stemmed	100.0	80.0	.....	20.0	23.7	4.2:1	3.4:1
Raspberries	100.0	100.0	100.0	....	14.8	6.8:1	6.8:1
Strawberries, four varieties	100.0	96.4	.....	3.6	16.7	5.9:1	

After drying, the fruit was again carefully weighed and representative samples withdrawn, which were later analyzed for moisture and sugar. The figures obtained are given in Table 70.

TABLE 70.—COMPARATIVE YIELDS BY SUN DRYING AND DEHYDRATION OF VARIOUS FRUITS

Fruits and method of drying	Drying ratio	Moisture in dry fruit, per cent	Pounds dry fruit per 100 pounds fresh		Per cent of sugar in dry fruit	
			As weighed from tray	On 25 per cent water basis	As weighed from tray	On 25 per cent water basis
Apricots:						
In sun	5.1:1	15.6	19.7	22.1	50.1	47.5
In Univ. dehydrater	4.6:1	25.8	21.6	21.4	43.8	47.2
Peaches:						
In sun	4.8:1	17.8	20.9	22.9	49.1	44.8
In Univ. dehydrater	4.5:1	23.7	22.1	22.5	47.9	47.0
Prunes:						
In sun	1.5:1	15.0	66.2	74.8		
In Univ. dehydrater	1.5:1	14.4	67.1	76.3		

Consistently higher yields of dried prunes were obtained by dehydration, but for other fruits no appreciable difference in yield was noted by

the two methods. The dehydrated fruits were superior in flavor and cooking quality to the sun-dried fruits, although not so attractive in appearance in some instances.

Apples (see also Table 73).—There is an increasing demand for dehydrated apples of the highest quality, although the tendency in the past has been to produce quantity rather than quality, with the result that much of the usual commercial pack is only suitable for cheap export markets. The cleanest, whitest fruit that is well trimmed and carefully dried and packed is most in demand. In seasons of abundant crops and low prices for fresh fruit, large quantities of apples that would normally be sold fresh are dried, and the grade of the dried product is correspondingly improved. In years of light crops, when all apples suitable for packing are in demand at high prices, only the poorer fruit is dried with, generally, a lowering of the quality of the dried fruit.

Varieties.—Dried apples are graded on texture and appearance rather than on flavor. Varieties that are firm and yield a dried product of white color are therefore preferred. In California, of the commercially grown varieties, the Yellow Newtown Pippin is the best for drying. In Oregon and Washington the Esopus (Spitzenberg) is in demand for drying purposes. The Baldwin, Hubbardston, and varieties of the Russet group are also satisfactory. The Gravenstein is one of the best of the early varieties for drying purposes. The Bellflower and some other important varieties yield dried products of yellowish color and are not greatly in demand for drying.

Sorting.—The apples should be carefully sorted to remove rot, wormy fruit, etc., and if possible, thoroughly washed before peeling. Sorting can be done on a broad belt.

Spray Removal.—If the peels and cores are to be utilized for vinegar making, stock food, etc., the apples must be washed in warm dilute hydrochloric acid solution (1½ to 3 per cent) and rinsed in order to remove lead arsenate spray residue.

Peeling and Coring.—Apples are peeled and cored in one operation by a machine operated either by hand or by power. The peeling is done by a guarded blade similar to a safety razor. The peeling machine is also often equipped with a knife which cuts the peeled and cored apples into a spiral, which gives rings when cut crosswise. In many drying plants in order to facilitate trimming of the peeled fruit, the fruit is merely peeled and cored in the peeling machine and is sliced in a separate machine. A "seed celling" attachment also is often used.

Trimming.—Trimming is of great importance because some of the peeled fruit carries pieces of peel, bruises, or portions of the calyx, which must be removed if a dried product of high quality is desired. There should be at least two workmen trimming for each workman engaged in

peeling. Trimming can be done efficiently by girls or women stationed beside a slow-moving belt, or at sinks supplied with fruit by a belt which passes beneath the peeling machines.

Sulfuring.—Apples are always exposed to the fumes of burning sulfur before drying, in order to bleach the surface of fruit which has become brown by exposure and to prevent further browning. The whole peeled fruit may be sulfured before slicing, in which case 45 to 90 minutes' exposure is required; or it may be sulfured after slicing, when 20 to 30 minutes' sulfuring will be sufficient. The fruit is either sulfured on the trays in the same manner as other fruits, or may be sulfured on a wooden slat conveyer in a long chamber.

If the sliced apples are dipped in a 3 to 5 per cent salt solution, the period of sulfuring may be reduced to 15 min. Recently Mrak of University of California has found that dipping the fruit in a dilute (1 to 3 per cent) metabisulfite or bisulfite solution prevents subsequent browning of the apples in storage. This treatment is given before sulfuring or, if severe, may replace sulfuring.

Cubing.—Apples are usually cut in slices (rings) about ¼ in. thick, but a demand also exists for cubed dehydrated apples. Cubes about ½ in. in size are cut from the whole, peeled, trimmed and cored fruit by a special machine. These dry quickly and are convenient for use in pies.

A large fruit-dehydrating company formerly operating in Oregon sliced the apples (before drying) in very thin pieces by means of a sauerkraut cutter.

Driers Used.—On the Pacific coast, apples are generally dried on trays in a tower, Oregon tunnel driers, or air-blast dehydraters, while in New York and other apple-growing sections of the eastern United States the kiln drier is more popular than those in which trays are used.

Temperatures.—In stack driers in California a temperature of approximately 180°F. is used for drying the lowermost trays in each stack or tower. In air-blast dehydraters a lower temperature, 140 to 175°F., is employed. The lower temperature is less liable to cause browning of the color and caramelization of the sugar.

Drying Time.—The drying time for sliced apples in the stack drier is about 10 to 12 hr.; cubed or thinly sliced apples dry more rapidly. Apples lend themselves well to use of the parallel-current system by which it is possible to dry them in 2 to 3 hr.

Yields.—In California approximately 7 tons of fresh, unsorted, unpeeled fruit is required to give 1 ton of dried product. In the Pacific northwest, on account of the lower sugar content of the apples, about 8 to 10 tons of fresh fruit is required to yield 1 dry ton. Yields also vary greatly with different varieties. 10:1 to 14:1 yield

Moisture Content.—Government regulations require that dried apples contain not more than 24 per cent of moisture when offered for sale.

Storing Dried Product.—The dried fruit is usually stored in large bins or in heaps on the storeroom floor, which is generally located in the basement of the building in which the drier is housed. Care should be taken to exclude insects. The packing of dried apples is discussed in Chap. XXII.

Resulfuring.—Some packers moisten the dried apples from storage and sulfur them in fumes of burning sulfur before final packaging. Spraying with dilute bisulfite or metabisulfite solution may accomplish the desired result also.

Dehydration of Apricots.—Apricots are prepared as for sun drying, although 1 hr. of sulfuring is usually sufficient as contrasted with 3 to 5 hr. for fruit which is to be dried in the sun.

A temperature less than 160°F. should be used for apricots near the end of the drying period; best results are obtained at temperatures below 150°F.

Bananas.—This fruit is dried to a limited extent in the tropics in driers of various types. Green fruit is peeled after loosening the skin by blanching. The peeled fruit is sulfured a short time, dried on trays until brittle, ground, and bolted to make banana flour. Ripe bananas are peeled and dried whole. These are known in commerce as "banana figs." They are of dark color and unattractive appearance but of fairly pleasing flavor. If the ripe fruit is sliced lengthwise and sulfured for 20 min. before drying, a much more attractive product is obtained.

Large quantities of bananas go to waste in the tropics in the groves and at export ports because of slight blemishes, overripeness, etc. Dehydration is a means of conserving much of this fruit and rendering it available as food.

Cherries.—Cherries should be dipped in dilute boiling lye solution (¼ to ½ per cent sodium hydroxide) and rinsed in water.

White or pink cherries should be sulfured about 15 min. Black cherries require a short sulfuring if it is desired to retain the natural fresh color. See Table 73 for additional information.

Cherries may be pitted before dehydration and then require no lye dipping before drying. Dehydrated pitted cherries are excellent for pies, etc.

Figs.—Whole white figs, which have been allowed to ripen, to partially dry on the trees, and to drop to the ground before gathering, can be dehydrated whole in 9 to 12 hr. at 165°F. If cut in half, drying is much more rapid.

Grapes.—Grapes should be lye dipped before dehydrating. Muscat and wine grapes possess tough skins and require a relatively strong solu-

tion (2 to 3 per cent sodium hydroxide), while Sultanina (Thompson Seedless) and Tokay are tender-skinned and a dilute lye solution (¼ to ½ per cent sodium hydroxide) checks the skins satisfactorily. Sulfuring is not necessary, although the color is improved; it has become general practice in the dehydration of seedless grapes (see below).

Grapes respond well to the parallel-current system of drying, with an initial temperature of 200°F. and a finishing temperature of 160°F. In general practice, however, the counter-current system is employed with an initial temperature of 110 to 120°F. and a finishing temperature of 160 to 165°F. Dipped grapes may be dried in 20 to 30 hr. by the counter-current system with a finishing temperature of 165°F.

Dehydrated white grapes, such as Muscat and Thompson Seedless varieties, are inclined to be more sticky on the surface than the sun-dried raisins and are usually lighter in color. So-called "golden bleach Thompson Seedless" raisins are now produced in considerable quantity by lye dipping, sulfuring for about 3 hr., and dehydrating. The grapes must be thoroughly ripe in order to give raisins of satisfactory color and texture. Exposure to the sun for 1 day after sulfuring destroys any green color present. There is a good export demand for "golden bleach" raisins.

Loganberries.—This fruit was formerly dried commercially in the Pacific northwest both in large forced-draft commercial plants and in farmers' driers of the Oregon tunnel type. No preliminary treatment, other than sorting, is necessary. Berries for drying should be firm ripe, for soft-ripe fruit is apt to melt and form "slabs" and to lose a great deal of juice. For the same reason the berries should not be washed (see Table 73).

The parallel current has been used successfully both in Oregon tunnel natural-draft driers and in forced-draft dehydraters. In the latter method an initial temperature of 180°F. and a finishing temperature of 145 to 150°F. can be used. A large company formerly operating plants at The Dalles and at Salem, Ore., dried large quantities of loganberries very successfully at temperatures below 145°F. in an air-blast dehydrater.

Peaches.—Peaches should be halved, pitted, and lye peeled as for canning. The halves are spread on the trays, cups upward. Slat trays, heavily coated with slab oil (neutral mineral oil), should be used in order to prevent sticking to the trays. The peaches should be sulfured about 3 hr. if a light-colored product is desired. There is also a small demand for unsulfured dehydrated peaches. Darkening of unsulfured peaches can be greatly reduced by blanching in steam on the trays until the halves are heated through to 185 to 212°F., normally about 5 min. in live steam.

Peaches tend to caseharden seriously and on this account the relative humidity should be increased to about 30 per cent during the final stages

of drying, and because of their tendency to caramelize, peaches should not be dried at temperatures above 145°F. The drying under these conditions is about 30 hr.

Clingstone canning varieties yield an excellent dehydrated product and dehydrated freestone peaches, such as the Muir, Lovell, Elberta, and Crawford, are equal in appearance and superior in flavor and cooking quality to the sun dried. Cling peaches have been dehydrated whole successfully after lye peeling, slitting lengthwise to the pit to hasten drying, sulfuring 12 to 15 hr., and dehydrating.

Sliced peeled peaches yield a particularly attractive dehydrated product.

Pears.—Bartlett pears should be peeled and cored as for canning because the unpeeled halves prepared as for sun drying are not so attractive dehydrated as sun dried.

The peeled halves are sulfured as described above for peaches, and drying times, temperature, and desirable relative humidity are about the same as for peaches. Pears may also be cubed or sliced, if desired.

Dehydrated pears are markedly superior to the sun-dried pears for culinary purposes, and after 24 hr. refreshing in water, the fruit resembles the canned product in appearance and flavor (see Tables 69 and 73).

Dehydration of Prunes in California.—Prunes are prepared for dehydration in the same manner as for sun drying, although lye dipping should not be so severe because "heavy" dipping causes the dehydrated prunes to be sticky. Many prunes are now dipped in boiling water only before dehydration. Screen trays may be used, but slat trays are more durable and can be used for other fruits also. The dipped fruit is spread on the trays one layer deep.

Drying.—Prunes "drip" badly if the parallel-current system is used; better results are obtained with the countercurrent, using an initial temperature of 110 to 130°F. and a finishing temperature of 160 to 165°F.

The relative humidity near the end of the drying period should be at least 20 per cent because of danger of casehardening. This can be attained usually by recirculation of the air. The drying time is 24 to 36 hr. in the driers now in use on the Pacific coast.

Cost of Dehydration.—Although most of the prune crop in California is dried in the sun, interest in dehydration is increasing and many dehydraters have been built. At present, approximately 15 to 20 per cent of the crop is dehydrated. Christie made a survey of sun-drying yards and dehydraters and compiled the comparative costs of sun drying and dehydration as given in Table 71.

Labor costs are less in dehydration than in sun drying, and the saving in cost of this item partially compensates for the extra cost of fuel and power in dehydration.

TABLE 71.—COMPARATIVE COSTS OF SUN DRYING AND DEHYDRATION OF PRUNES IN CALIFORNIA ON BASIS OF GREEN TON OF FRUIT
(*After Christie*)

Item	Dehydrater A	Dehydrater B	Dehydrater C	Dehydrater D	Dehydrater E	Average for dehydration	Average for sun drying
Labor	$1.90	$2.45	$2.78	$2.81	$3.42	$2.67	$3.68
Fuel	0.48	0.62	1.02	0.89	1.34	0.87	0.18
Power and light	0.65	0.65	0.74	0.86	1.03	0.79	0.04
Lye	0.04	0.07	0.08	0.15	0.07	0.08	0.09
Total	$3.07	$3.79	$4.62	$4.71	$5.86	$4.41	$3.99

Yields by Sun Drying and Dehydration.—Christie's experiments indicate a higher yield by dehydration than in sun drying. A ton of fruit carefully selected for uniformity of size and maturity was divided into two lots which were further sorted into No. 1 and No. 2 fruit by a fresh-fruit grader. One lot of each grade was partially dried in the sun and stacked; and drying was completed by the most approved sun-drying methods. One lot of each was dehydrated in a commercially operated air-blast dehydrater. Samples of the dried products were analyzed for moisture content and yields were calculated to a basis of common moisture content with the results given in Table 72.

TABLE 72.—COMPARATIVE YIELDS OF FRENCH PRUNES BY SUN DRYING AND DEHYDRATION
(*After Christie*)

Size	How dried	Drying ratio	Pounds of dry per 100 pounds fresh on 25 per cent moisture basis	Count per pound
No. 1	Sun dried	2.34	42.7	43
No. 1	Dehydrated	2.16	46.3	42
No. 2	Sun dried	1.84	54.2	47
No. 2	Dehydrated	1.82	54.9	43

Dehydration yielded at the rate of 1,012 lb. per green ton and sun drying 969 lb., an appreciable difference in yield in favor of dehydration. The quality of the dehydrated prunes was found to be equal to, or better than, that of the sun dried.

Dehydration of Prunes in Oregon.—In the Pacific northwest the Oregon tunnel is used for drying prunes at the orchard or in large centrally located plants owned by growers' organizations. The Italian prune, a tart variety, is grown almost exclusively. It is advertised in eastern markets

as the "Mistland" tart-sweet prune. The fruit is lye dipped to check the skins and is placed on screen trays which are entered at the upper end of the tunnels at about 100 to 130°F. A temperature of 180 to 190°F. is commonly used and 200°F. is not uncommon near the end of the drying period, resulting in some caramelization.

Variation in temperature in these driers when wood is used for fuel is very great. A superior product is obtained by drying in carefully controlled forced-draft dehydraters at temperatures not above 150°F. Such dehydraters are now common in the Pacific northwest.

The efficiency of the Oregon tunnel is much increased by the installation and use of a fan for recirculation of the air, as shown by Wiegand of the Oregon Agricultural College.

Lewis recommends that Italian prunes be dried to a moisture content of 17 to 18 per cent. However, if dried to a very low moisture content in an Oregon tunnel, there is great danger of scorching.

Other Fruits.—Persimmons lose all of their astringency ("pucker"), when peeled and dehydrated, if not previously sulfured. They should be peeled and cut in quarters or sliced. They are sweet and of pleasing flavor.

Raspberries dry quickly and require no preliminary treatment except sorting. The black variety may be successfully dried on a kiln floor but better results are obtained on trays. Temperatures above 145°F. are not desirable.

Strawberries "drip" badly unless drying is started at a temperature of 100 to 110°F. A short period of sulfuring (15 to 20 min.) improves and fixes their color.

Citrus fruits are dried in limited quantities for use in preparing a flour or meal for flavoring purposes. The whole fruit is sliced, sulfured about 30 minutes, and dried "bone dry." It is then ground and is used in this form in limited amounts by bakers and confectioners. Waste orange peels are dried in rotary drum direct-fired dehydraters for use as stock food.

Pickled ripe olives were at one time dehydrated in California but were not in great demand. If pitted before drying, ripe pickled olives yield an excellent dried product for flavoring meat dishes, etc. They possess a mushroom-like flavor. If heated in an oven after drying or if heated *in vacuo* at about 200°F., they will become plump and somewhat like popcorn in specific gravity.

Drying of Walnuts.—The dehydration of walnuts has largely superseded sun drying. Although in use as early as 1889, dehydration of walnuts did not come into general use until about 1920 to 1925. Present practice is based to a great extent on the investigations of Christie and Nichols (see references at the end of the chapter).

Unlike fruits, walnuts after hulling and washing are placed in bins rather than on trays. Warm air not above 110°F. is forced through the bins until the nuts are dry (contain less than 10 per cent moisture). Christie and Guthier showed that nuts dried at temperatures above 110°F. often became rancid in subsequent storage after drying; evidently because the higher temperatures caused some of the oil to exude to the surface of the nuts where it later rancidified.

If the bin is deep (3 ft. or deeper), the air current should be reversed in direction at regular intervals during drying in order to secure uniform drying. On warm, dry days, the air need not be heated, and thus fuel is conserved. Natural gas is the preferred fuel, although crude oil and other fuels are used when gas is not available. Electrical heating has been used in some cases, but its cost is excessive.

In the Brown dehydrater several screen floors, one above the other, are used. When the nuts on the lower floor are dry, they are removed and those from the floor above are dropped on it to complete the drying. The nuts on the other floors, usually three in number (total of five floors for each unit), are also dropped one floor and fresh nuts are placed on the uppermost floor. Each floor is made up of narrow segments that may be tilted, thus making openings through which the nuts fall to the floor beneath. Plans and directions for building and operating this drier may be had from the Agricultural Engineering Division, University of California.

By experience the operator can judge fairly closely the moisture content of the nuts. They should be dried to about 8 to 10 per cent moisture. Usually moisture tests are made occasionally to confirm visual judgment. When the nuts are sufficiently dry, the membrane between the halves of the kernel becomes brittle. Moisture is determined by drying 50 grams of the crushed whole nuts, in an oven at 100°C., to constant weight or by distillation in a xylene moisture still, now obtainable from leading chemical glassware supply houses (see Nichols, Fisher, and Parks).

If the nuts are overdried, they will later take up moisture in the packer's warehouse, and the dehydrater operator loses the corresponding weight. Since walnuts are valuable (usually worth 15 to 20 cents a pound) this loss may be appreciable. If not dried sufficiently, the nuts cannot be processed properly at the packing house, they may become moldy, or the meats may darken badly in storage.

A convenient means of bringing the nuts to the proper moisture content is to store them several days in slatted bins after removal from the dehydrater, in order to permit them to establish equilibrium with the moisture of the surrounding air.

Summary of Dehydration of Fruits.—The following table summarizes recommended procedure for various fruits:

TABLE 73.—RECOMMENDED METHODS FOR DEHYDRATION OF VARIOUS FRUITS
(*After Cruess and Christie*)

Variety of fruit	Pounds per square foot on trays	Hours sulfured	Maximum temperature at end of drying period, °F.	Desirable humidity in tunnel dehydrater at end of drying period, per cent	Drying time by counter-current method, hours	Remarks
Apples	2	½	165	5–10	8	Peeled and sliced or cubed
Apricots	2	2	160	10	12	Halves unpeeled
Bananas	1 –2	½	165	5–10	12–18	Peeled, cut in half lengthwise
Cherries:						
Black Tartarian	2 –3	½	170	10–25	8–12	Lye dipped
Royal Anne	2 –3	¼	170	10–25	8–12	Lye dipped
Figs	2 –3	1	160	5	10	One side cut and figs spread open
Grapes:						
Muscat	3½–4	½	160	5	24	Lye dipped
Seedless	3½–4	3	160	5	16	Lye dipped
Wine	3½–4	1	160	5	20	Lye dipped
Loganberries	1½–2	½	160	10–25	10–15	Untreated
Peaches	3	3	150	20–30	24	Not peeled
Peaches	3	2	150	20–30	16	Lye peeled
Pears	3	24	145	30–40	48	Halves unpeeled
Pears	2	½	150	10–20	6	Peeled and sliced
Pears	2	3	150	10	16	Peeled and cored
Prunes:						
Italian	2½–4	0	170	20–30	24	Lye dipped
French	2½–4	0	165	20–30	24	Lye dipped
Imperial	3 –4	0	165	20–30	30–36	Lightly dipped
Raspberries	1½–2	0	170	10–25	8–12	Untreated
Strawberries	1½–2	½	160	10–25	24	Stemmed

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CHAPTER XXII

DEHYDRATION OF VEGETABLES

Unlike fruits, vegetables do not lend themselves well to sun drying. Sun-dried vegetables are tough, unattractive in appearance, bleached in color, and of poor flavor. Dehydrated vegetables, on the other hand, are often equal to the canned products in quality.

Vegetables may be grouped into two classes: those that are canned but that can be successfully dehydrated, such as spinach, sweet potatoes, corn, peas, string beans, tomatoes, pumpkin, cabbage, and beets; and those which are well adapted to dehydration but which are seldom canned, such as potatoes, turnips, carrots, celery, onions, and sprouts.

Comparison with Canned Vegetables.—When compared with the canned products it is found that dehydrated vegetables possess several advantages. They weigh from one-fifth to one-twentieth as much as the canned products and are of from one-half to one-tenth the volume. This results in a great saving in containers and in transportation charges. Their principal disadvantage lies in the fact that they require "refreshing" (soaking) in water several hours before cooking.

Table 74 gives the relative weights of various canned and dehydrated vegetables obtained from 1 ton of the fresh vegetables.

TABLE 74.—RELATIVE WEIGHTS OF CANNED AND DEHYDRATED VEGETABLES FROM 1 TON OF THE FRESH PRODUCTS
(Weights of containers included)
(*After Prescott*)

Vegetable	Weight prepared for canning or dehydration, pounds	Weight canned and packed, pounds	Weight dehydrated and packed, pounds
Corn	750	1,426	465
Peas	1,960	4,291	350
String beans	1,500	3,832	200
Lima beans	800	2,300	250
Tomatoes	1,100	1,763	125
Pumpkin	1,400	2,146	200
Sweet potatoes	1,450	2,250	513
Cabbage	1,450	2,400	215

Present Status.—Since the war the interest in dehydrated vegetables has declined, with the possible exceptions of onions and garlic for powdering. Potato flour has been a standard product for a number of years and is used extensively for mixing with wheat flour in making bread, where it serves as a yeast food, and it is also used as a sizing for cloth. In continental Europe dehydrated vegetables are more popular than in the United States. Precooked ground and compressed vegetables for use in soups are common in Germany and Switzerland. Holland also produces considerable quantities of dehydrated vegetables.

Food Value of Dehydrated Vegetables.—Dehydration does not alter the chemical composition of vegetables except by concentrating all constituents except water. It is believed that there is some loss in the antiscorbutic vitamin C when the cooked fresh vegetable is compared with the same vegetable after dehydration and cooking.

Prescott has compiled analyses of fresh and dehydrated vegetables and a few of his analyses are shown in Table 75.

TABLE 75.—COMPARATIVE FOOD VALUE OF FRESH AND DEHYDRATED VEGETABLES
(*After Prescott*)

Vegetable	Per cent, water	Per cent, protein	Per cent, total carbohydrates	Fuel value per pound calories	Ratio fuel value of fresh to dehydrated
Cabbage, fresh, edible portion	91.5	1.6	5.6	145	1:10.6
Cabbage, dried	10.0	16.9	59.3	1,536	
Corn, green, edible portion	75.4	3.1	19.7	470	1: 3.7
Corn, dried	10.0	11.3	72.1	1,720	
Peas, green, edible portion	74.6	7.0	16.9	385	1: 3.5
Peas, dried	10.0	24.8	59.8	1,646	
Potatoes, fresh, edible portion	78.3	2.2	18.4	385	1: 4.1
Potatoes, dried	10.0	9.1	76.4	1,598	
Pumpkins, fresh, edible portion	93.1	1.0	5.2	120	1:13.0
Pumpkins, dried	10.0	13.0	67.8	1,565	

Washing.—Root vegetables and tomatoes particularly require thorough washing, for which the rotary tomato washer is generally well suited. The same principles and methods apply in washing vegetables for dehydrating as for canning.

Peeling and Trimming.—Mechanical peelers can be used in the preparation of potatoes and most other root vegetables. A successful type of peeler for this purpose consists of a steel cylinder, about 30 in. in width and about 16 in. in depth, the sides and bottom of which are coated with coarse carborundum crystals which act as an abrasive surface. The bottom of the peeler revolves rapidly and rubs the vegetables against the rough surface, thus grating the peels from them. A heavy spray of water washes away the peels.

The peeling is not perfect and considerable hand trimming is necessary. A machine of approximately the above dimensions was found to have a capacity of about 50 lb. of potatoes per charge which was peeled in 45 sec. The loss in the peeler was about 36 per cent and in trimming about 2 to 3 per cent.

Onions are usually peeled by hand, as the mechanical peeler either breaks the vegetable too much or does not remove the outer dry husks satisfactorily.

Carrots, white potatoes, turnips, and parsnips can be peeled satisfactorily in the above type of mechanical peeler. Beets and sweet potatoes are peeled as for canning, by first steaming or cooking in a retort to loosen the skins, followed by hand peeling.

Carrots and sweet potatoes may also be peeled very satisfactorily with boiling 10 per cent lye.

Tomatoes are greatly improved by peeling before dehydration, although it is customary to omit this operation, trimming and slicing constituting the usual procedure.

Peppers and pimentos are dehydrated without any preliminary treatment other than sorting. Cabbage heads are cored, and the outer leaves are removed and discarded; corn is husked as for canning which may be done mechanically. Spinach is trimmed and is then very thoroughly washed as for canning in order to remove sand and insects.

String beans and peas are prepared as for canning. Egg plant, pumpkin, and okra are usually not peeled.

Slicing, Cubing and Shredding.—Vegetables to be used in soup mixtures are shredded or cubed mechanically after peeling.

Potatoes are either cubed or are sliced to about ⅛ in. in thickness. They are sometimes cut in rectangular strips as for French-fried potatoes.

Cabbage is shredded in a sauerkraut slicer or in a rotary type of vegetable slicer.

Blanching and Precooking.—Most vegetables lose their color and flavor rapidly after drying, unless they are blanched in steam or boiling water before drying. Blanching destroys the enzymes responsible for a great deal of the undesirable change occurring in dried vegetables, hastens the rate of drying in many cases and arrests changes which tend to

make the vegetables tough and difficult to cook. It also intensifies and fixes the color in some cases. Some vegetables, however, *e.g.*, tomatoes, onions, and peppers, are not improved by blanching.

Cabbage should be blanched in live steam about 2 min. on screen trays.

Nichols and Gross found that carrots gave the best dehydrated product when blanched in a boiling 2 per cent salt solution for 2 to 4 min.

Celery does not require blanching if to be used for powdering. Corn, after husking, should be blanched on the cob for 5 to 10 min. to "set the milk." Okra should be sliced and blanched about 2 min. in boiling water; peas and string beans should be blanched in live steam on screen trays 3 to 10 min., depending upon their maturity. Potatoes are usually blanched in steam, but more uniform results and less overcooking of the edges of the pieces result from blanching in water at 180 to 190°F. for 4 min. or in boiling water about 3 min. Blanching gelatinizes the loose starch granules on the surface of the pieces and causes them to stick together or to stick to the trays, and the blanched potatoes should, therefore, be rinsed free of this starchy material in cold water before traying.

Sweet potatoes may be treated in the same manner as Irish potatoes, but usually the whole unpeeled potatoes are steamed until the skin will slip readily and until the vegetables are cooked through but not mealy; after this they may be peeled and cubed or sliced.

Pumpkin is not usually blanched before drying for flour, but its color and keeping quality are improved by blanching in steam on the trays for 2 or 3 min. Pumpkin is peeled and sliced before traying.

Spinach and other greens become unduly brittle and tomatoes soften badly if blanched severely. Spinach and other greens should be blanched on screen trays for about 2 to 3 min. in live steam. Turnips and parsnips are blanched as described above for carrots.

Blanching Equipment.—In general, blanching in water permits of more careful regulation than blanching in steam, although the loss in soluble solids is greater in water than in steam blanching. Steam blanchers are of two types: (1) A cabinet fitted with perforated steam pipes; (2) an enclosed steam box similar in appearance to an exhaust box, through which the vegetables pass on trays and conveyer or on a woven metal-cloth conveyer (see Fig. 90).

Water blanching may be made continuous by use of a conveyer or may be done with baskets in small tanks of boiling water.

Sulfuring.—Potatoes to be dried for making flour for the textile industry are sulfured; other vegetables should not be sulfured.

Trays.—Screen trays of $\frac{1}{8}$-in. mesh are satisfactory for vegetables, except for small peas. Slat trays are not so suitable because of loss of the dried products through the spaces between slats. Vegetables do not react

upon the metal so vigorously as fruits because they are less acid and less juicy.

Temperatures of Drying.—Most vegetables give up their moisture readily, and on this account the parallel-current system of drying can be used to advantage. An initial temperature of 180 to 185°F. and a finishing temperature of 140 to 145°F. can be used and very rapid drying rates obtained. The finishing temperature should not exceed 150°F. for most vegetables. If the counter-current method is used, high air velocity may be used to reduce the drying time.

Drying Times.—Most vegetables, as prepared and dried commercially, dry in less than 6 hr. Spinach can be dried in 2 hr. and potatoes usually require 6 to 8 hr. by the counter-current system.

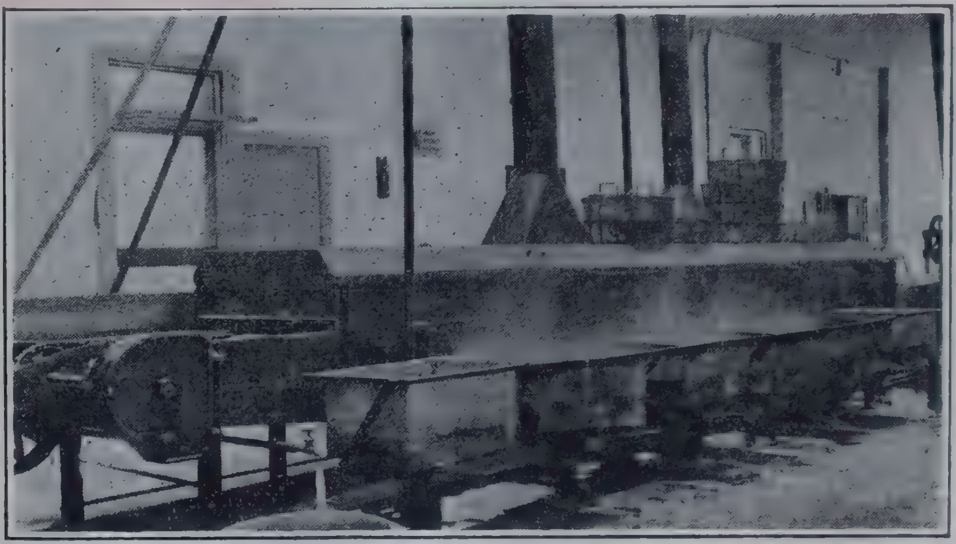

FIG. 90.—Large steam-heated blancher for vegetables on trays and small blanching tanks and baskets.

Moisture Content.—Nichols and others have found that the moisture content of dehydrated vegetables must be less than 8 per cent and preferably less than 6 per cent in order to retard harmful enzymatic changes in color and flavor during storage after dehydration. Unblanched vegetables deteriorate more rapidly than the blanched products because of acceleration by oxidizing enzymes.

Above 20 per cent moisture, dehydrated vegetables will generally mold in sealed containers. The upper limit for fruits is about 25 per cent. The sugar in dried fruits exerts some preservative action, and its lower concentration in dried vegetables accounts for their greater susceptibility to molding.

DEHYDRATION OF VARIOUS VEGETABLES

In order that the description of the preparation and drying of the more important vegetables may be as complete as space permits, the following additional information is given.

Potato Flour for Use in Baking.—In preparing potato flour by the flake process, for use in baking, the following steps are involved: The potatoes are first washed thoroughly, then peeled mechanically and trimmed by hand, if to be used for the best grade flour, although peeling is sometimes omitted.

They are cooked in a retort under 15 lb. steam pressure for 15 to 25 min., which reduces them to a mealy consistency. They are then passed between steam-heated steel cylinders, which have a smooth surface and revolve closely together. Steam at about 60 lb. pressure is used in the cylinders. The potatoes are compressed to a very thin layer and dried bone dry by contact with the hot surface of the cylinders. Mechanical scrapers remove the dried product, which falls in flake-like form to a conveyer.

The flakes are ground at once and bolted to yield a flour which compares favorably with wheat flour in food value, although it is somewhat lower in protein.

The flake process is used extensively in Europe, but there are only a few plants in America.

Flour from Sulfured Potatoes.—In a California plant during the World War the following method was used in drying potatoes for flour for use in the textile industry. The potatoes were soaked to loosen adhering soil and then thoroughly washed, peeled, and sliced mechanically. The sliced potatoes were sulfured in the fumes of burning sulfur on a wooden slat conveyer in an enclosed rectangular box and were then spread and dried at 200°F. on the belt of a three-conveyer air-blast dehydrater. The dried pieces were then ground and bolted.

Prescott and Mangels attempted to prepare sweet potato flour by the flake process but found that it was hygroscopic and soon became lumpy and of little value as flour.

Dehydration of Potatoes for Table Use.—During preparation for dehydration the potatoes are washed, sorted, mechanically peeled, and carefully trimmed by hand. They may then be sliced about 3/16 in. thick or cubed. They are blanched from 2 to 5 min. in water at 180 to 212°F. and rinsed in cold water.

Blanched potatoes caseharden if the relative humidity during drying is very low, and at temperatures above 150°F. the color is apt to become reddish-brown.

Potatoes, properly prepared and dehydrated, should be white or very light yellow in color and translucent and should be dried until hard and brittle. When broken between the fingers, the fracture should be sharp, and the interior of the pieces should be flinty and not mealy. The drying ratio is from 5 to 7:1.

Sweet Potatoes.—The potatoes are peeled as for canning. They may be dried in a number of different forms, *e.g.*, cut in halves or quarters lengthwise to be used for baking, sliced for frying, or whole for baking, boiling, etc. They are not so sensitive as white potatoes to heat and may be safely dried at 175°F.

The drying ratio is about 3.5:1, a higher yield of dried product than from any other common vegetable. They should be dried until brittle, otherwise molding is apt to occur during storage.

Onions.—Onions should be trimmed and peeled by hand and should be cut in very thin pieces because of the tendency of thick pieces to case-harden, to dry very slowly, and to darken.

Blanching is undesirable, because it causes the onions to stick to the trays and does not improve their appearance. Immersion of the sliced onions in cold 5 per cent salt solution for 3 to 5 min. before drying reduces their tendency to darken during drying and later in storage.

A temperature of 140°F. should not be exceeded during dehydration, because of darkening of the color and loss of flavor at higher temperatures. The drying ratio is from 10:1 to 15:1.

Dehydrated onions are ground by hammer mill to a flour extensively used for flavoring stews, gravies, commercial meat products, etc.

Carrots and Other Root Vegetables.—These vegetables include carrots, turnips, beets, and parsnips. They are prepared for drying as described in the paragraphs on preparation and blanching.

They may be dried rapidly, as they will withstand relatively high temperatures (165 to 175°F.), and should be dried until hard and brittle.

Pumpkin.—Pumpkin and squash are dehydrated for the preparation of "pumpkin flour," a finely ground, coarsely bolted mixture of the two vegetables. In California a mixture of Connecticut field pumpkin and Boston Marrow squash was used when pumpkin flour was made commercially.

The pumpkins and squash were cut in half with large knives and the seeds and seed-cavity pulp removed. The unpeeled halves were sliced or shredded in a silage cutter or other heavily constructed cutting machine into pieces about ¼ in. thick. In most factories the pumpkin and squash were not blanched, but the color is greatly improved if the slices are steamed on the trays until heated through.

The vegetables were dried until very dry, less than 6 per cent moisture, and were ground in an attrition mill or hammer mill before they could absorb moisture and become leathery. The ground product was bolted or screened to remove the coarse particles, which were reground. The resulting flour was packed in small envelopes for household use or in large friction top cans for bakery, restaurant, and hotel use for pies. Canned pumpkin has replaced the dehydrated.

Tomatoes.—Tomatoes may be dried in sliced form unpeeled, but the quality is much improved by peeling before drying in the same manner as for canning.

Slices should be about ¼ in. thich and no blanching is required.

Temperatures below 150°F. should be used, as the slices darken at higher temperatures. They should be dried until the pieces show no moisture when pressed between the fingers, or until the slices will break crisply on bending. The color is improved if the sliced tomatoes are sulfured in the fumes of burning sulfur for 20 to 30 min. before drying.

The dried product may be packed in the form in which it comes from the trays; it may be ground to a meal which can be used in soups, etc., without preliminary soaking or the ground product may be pressed into bricks. The drying ratio is about 16:1.

Peppers and Pimentos.—Dried hot peppers are used in large quantities by the Mexican population of the southwestern United States and Mexico. A considerable quantity is dried for the manufacture of paprika, a sweet pepper powder for use on the table and in cooking. A great deal of the dried, hot red peppers are ground for packing as cayenne pepper.

The bags of well-ripened peppers are emptied on trays made of fine-mesh (about 1-in.) chicken netting attached to a frame of 1- by 3-in. material, the usual tray being about 2½ by 5 ft. The peppers are sorted to remove green and spoiled specimens. They are dried in natural-draft gas-heated driers at 130 to 160°F., a drying time of 3 to 5 days being required. The peppers are dried until brittle and until the seeds and pulpy portions are thoroughly dried.

Grinding of sweet peppers for paprika and of hot peppers for cayenne pepper is done in centrally located mills. The peppers must be dried to a very low moisture content and milled very shortly after drying, as they become tough with absorption of moisture.

Sweet Corn.—Corn has been dried in the sun or in ovens by housewives for many years, but its commercial-scale drying is of recent development. Properly dehydrated corn when soaked and cooked compares favorably with canned corn in quality, and it is cheaper. Only young tender ears of the best table varieties, such as the Country Gentleman and Golden Bantam, should be used for drying.

The ears are husked as for canning, and the corn is blanched on the cob in steam or boiling water for about 5 to 10 min. It is silked as for canning, cut from the cob, spread on screen trays, and dehydrated to a low moisture content. The dried product is subject to attack by insects and should be packed at once after drying or should be fumigated thoroughly before packing to destroy eggs of insects, such as the Mediterranean meal moth, etc.

Corn dries very rapidly and will withstand a finishing temperature of 150°F.

Several factories in the eastern United States were at one time successful in dehydrating sweet corn and marketing the product.

String Beans.—Dehydrated string beans have been one of the most popular vegetables dehydrated commercially. Dehydration intensifies any toughness the beans may originally possess and makes it imperative that only very tender beans be dehydrated.

The beans are snipped as for canning, are broken into short lengths, and are blanched in boiling water or live steam for 3 to 6 min., depending on the size and maturity of the beans. Caldwell recommends the addition of a small amount of sodium bicarbonate (about ½ per cent) to the blanching water to darken and fix the color.

The beans should be spread in a shallow layer on the trays; a deep layer dries very slowly and unevenly. They should be dried until both the pods and the beans in the pods are brittle. The drying ratio for young string beans is about 10:1.

Peas.—Peas for dehydration must be even less mature than for canning, because of the tendency of starchy peas to become tough-skinned and mealy during drying. The wrinkled varieties high in sugar content are much to be preferred to the starchy, smooth-skinned varieties.

The vines may be harvested as for canning and the peas separated from the pods and vines in the usual pea-vining machines (see Chap. XIII).

The peas are blanched in boiling water or live steam as for canning, for 2 to 5 min., depending on maturity, and spread on trays direct from the blancher in a layer about ¾ inch deep. The finishing temperature should not exceed 145°F., since high temperatures cause browning and loss of flavor. The center of the pea dries slowly, therefore peas should be dried until entirely crisp.

Spinach.—Spinach requires trimming, sorting, and very thorough washing before drying. Blanching consists in steaming on the trays 2 to 3 min. The washed leaves may be placed in a deep layer on the trays, provided air flow between trays is not seriously impeded.

The leaves dry very rapidly, and relatively high temperatures (175°F.) can be used. The stems, because of their greater thickness, dry more slowly than the leaves. The spinach should be dried to less than 6 per cent moisture and packed at once in packages which resist penetration of moisture. Spinach may be ground to a powder or pressed into briquettes if desired. The drying ratio is approximately 12 to 15:1.

Cabbage.—Cabbage is dehydrated rather extensively in Europe, where it is often packed in briquette form. The cabbage heads are

cored, the outer leaves removed and the heads shredded in a sauerkraut slicer. The cut cabbage should be blanched about 1 min. in live steam, which intensifies the color. A temperature of 145°F. should not be exceeded during drying. The cabbage is dried until crisp and should be packed if possible in moistureproof containers. On exposure to air, it darkens slowly and deteriorates in flavor. Undoubtedly vacuum-sealed cans would greatly improve its keeping quality. The drying ratio is approximately 15:1.

Cauliflower and Sprouts.—Brussels sprouts and cauliflower give fairly satisfactory dehydrated products. They are prepared as for cooking for the table, cauliflower heads, in addition, being broken or cut in smaller pieces. They are blanched in steam or boiling water 4 to 5 min. The temperature of drying should not exceed 140°F. because of their tendency to darken.

Okra.—Small pods may be dried whole and large pods should be cut lengthwise in halves or quarters or crosswise in circular pieces. Blanching in boiling water from 2 to 5 min. is advisable, followed by rinsing in cold water to remove the gelatinous coating formed in blanching. The finishing temperature should not exceed 140°F., and the drying ratio is approximately 10:1.

Celery.—Both the leaves and stalks of this vegetable may be dried and used for the flavoring of soups, stews, etc., or for the preparation of powdered celery or celery salt. Only tender stalks relatively free from "strings" should be used. The stalks are trimmed, washed, and sliced. Blanching renders the product more tender, 2 to 3 min. in steam or boiling water being sufficient. Celery leaves may be placed on trays separate from the sliced stalks; they require no blanching. The drying temperature should not exceed 140°F.

Rhubarb.—Rhubarb is grown quite extensively in many states, especially in proximity to large cities. In the early spring, before fresh fruits and summer vegetables are available, rhubarb brings very profitable returns in local markets. However, the demand and, consequently, the price soon decrease, and it oftens happens that much of the later rhubarb is never marketed. For dehydration the stalks are trimmed, washed, and cut into short lengths, which are spread and dried on trays at not above 175°F. The drying ratio is 13 to 15:1.

Garlic.—Garlic powder is made by grinding dehydrated garlic, and when mixed with cornstarch, it is a product of considerable merit. The outer paperlike coating of the "buttons" is removed mechanically. They are dehydrated without blanching; they are finely ground by hammer mill and may be mixed with starch or flour. The powder retains its flavor indefinitely and is excellent for flavoring gravies, stews, spaghetti, etc. A considerable quantity of garlic powder is produced in

California for use by restaurants, tomato products manufacturers, sausage makers, and other food producers.

Horse-radish.—This vegetable retains its pungency when dehydrated. The radish is washed, trimmed, grated, and dried at a moderate temperature, 140 to 150°F. It can be refreshed in water and used in the same manner as the fresh product.

Soup Mixtures.—Soup mixtures were used extensively by armies in the field during the World War and are still in demand for use on camping trips.

The pieces should be cut very thin or in small cubes or shreds so that they will cook quickly and should be thoroughly blanched before drying.

Various mixtures have been made. One recommended by Caldwell is: potatoes 20 parts, turnips 20 parts, peas 20 parts, onions 6 parts, and 17 parts each of carrots and beans. Flaked, cooked, dry white beans are used by one company to give a thicker consistency to the soup, and they make a valuable addition nutritionally because of their high protein content. Most soup mixtures contain celery in addition to the ingredients recommended by Caldwell, and tomato powder or shreds are an improvement. Turnips tend to become brown on storage and can, if the soup mixture is not to be used promptly, be eliminated.

In preparing soup mixtures it must be borne in mind that, since the mixture must subsequently be soaked and cooked as a unit, only such vegetables as absorb water and become cooked at approximately the same rate should be mixed. Peas and beans absorb water more slowly than the other vegetables named above unless they are cooked until almost ready for serving before they are dehydrated. Some European producers grind the dehydrated vegetable mixture and compress it into pellets or cylinders in order to conserve space and to give a product that cooks quickly.

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CHAPTER XXIII

PACKING OF DRIED FRUITS AND VEGETABLES

The packing of sun-dried fruits is an industry separate and distinct from that of drying, although dehydrated fruits are in many cases packed in the same plants in which they are dried.

Dehydrated vegetables are generally packed in the same building in which they are dried.

Importance of Dried-fruit Packing Industry.—Table 56 shows the growth of the dried-fruit industry in California.

Approximately 15,000 tons per year of dried figs are packed in Smyrna. Greece, Asia Minor, and Spain pack and export large quantities of raisins and Egypt, northern Africa, and Asia Minor produce most of the world's supply of dates. These fruits are in part packed ready for use, but much of the crop is shipped in bulk to America and Europe and is there processed and packed in cartons or boxes.

Oregon produces approximately 25,000 tons of dried prunes per year, while New York is a large producer of dried apples.

DRIED-FRUIT INSECTS

Insects cause in the aggregate enormous damage to dried fruits and vegetables and heavy financial losses to growers, packers, distributors, and consumers. Many of the operations of packing dried fruits and vegetables have for their purpose the destruction of insects and insect eggs and the exclusion of insects from the packed products.

General Types of Infestation.—Three groups of insects are of importance in causing damage to dried fruits and vegetables. The most important group is that of the moths, including the Indian-meal moth (*Plodia interpunctella* Hubn), the fig moth (*Ephestia cautella* Walk), and the raisin moth (*Ephestia figulilella* Gregson).

Beetles are second in importance, of which the most common in dried fruits are the dried-fruit beetle (*Carpophilus hemipterus* L.), the saw-toothed grain beetle (*Silvanus surinamensis* L.), the foreign grain beetle (*Cathartus advena*, Waltl), and a fungous beetle (*Henoticus serratus* Gyll).

The third group of insects includes two sugar mites (*Tyroglyphus siro* Gerv. and T. *longior Gerv.*). These mites are of very small size, scarcely distinguishable to the unaided eye.

Indian-meal Moth (*Plodia interpunctella* Hubn). —Essig comments as follows on this insect:

This insect is widely distributed and occurs not only in dried fruits but also in all cereal products, dry grains, seeds, nuts and many other foods. The larvae are yellowish-white and average about 1 inch in length. They are profuse web spinners and their webs, covering the fruit and containers, are more injurious to the appearance of the dried products than any other form of damage caused by this insect.

The fully grown larvae enclose themselves in small white cocoons about $\frac{1}{2}$ inch long. The chrysalids are brown.

The moths average from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch in length. They are readily distinguished from other moths by the distinctive two-colored pattern of silvery-gray and bronze, the anterior portion of the wings being silvery and the posterior half bronze or copper colored.

The very minute eggs are laid on or as near the dried products as possible, generally at night. The newly hatched larvae are very small and very active. They have a remarkable ability for locating dried fruit and will enter packages through very small cracks or other openings.

The remarkable reproductive power of this insect accounts for the sudden appearance in packing houses of enormous numbers of the larvae.

The moth is often found in dried fruit or refuse held over from the previous season. As a rule, public warehouses are infested with this insect and susceptible foods stored in such places invariably become infested. The appearance of this insect at various stages is shown in Fig. 91.

Fig Moth (*Ephestia cautella* Walk) is very similar in appearance and habits to the Indian-meal moth. The raisin moth, *Ephestia figulilella* Greg., resembles the other two moths in general appearance. It differs from them, however, in that it infests the fruit on the trays in the field, whereas the meal moth and fig moth are primarily indoor insects and breed in the warehouse.

Dried-fruit Beetle (*Carpophilus hemipterus* Linn.).—After Essig.

This is the most injurious of the beetles that infest dried foods. The larvae are small and whitish-yellow and are distinguished from the caterpillars of the dried fruit moths by the fact that they possess only three pairs of true legs, whereas the caterpillars possess three pairs of true legs and three pairs of fleshy prolegs.

The adults are short and robust, scarcely $\frac{1}{4}$ of an inch long. They are black in color, with reddish- or cinnamon-brown posterior portions. The larvae reduce the fruit to a fine powder or "frass," which is the excrement.

This insect ordinarily infests the fruit (particularly figs) while it is still in the field or dry yard. It is carried to the warehouses and packing houses in the fruit, where it thoroughly infests the premises. It is very active in laying eggs on figs during cooling of the fruit after processing (see Fig. 91).

The insect has marked ability to locate dried fruit and, like the Indian meal moth, reproduces with astonishing rapidity.

Saw-toothed Grain Beetle (*Silvanus surinamensis* Linn.).—After Essig.

Although of somewhat less importance than the dried fruit beetle, the saw-toothed grain beetle is, nevertheless, capable of causing extensive damage to dried fruits and vegetables. The larvae are small, about ¼ of an inch long and of whitish color. The adults are brown or blackish beetles ¼ of an inch long, slender and with saw-like teeth along the sides of the prothorax (neck). These teeth can be seen without a hand lens. They are particularly destructive to figs, not only destroying the inside of the figs, but also boring minute holes through the skins.

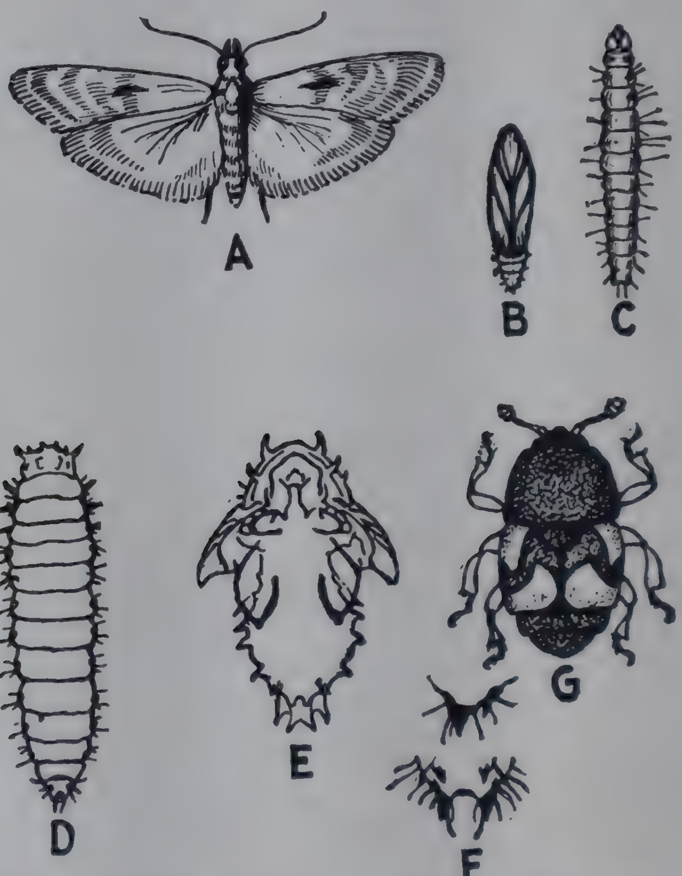

Fig. 91.—Common dried-fruit insects. *A*, adult of Mediterranean meal moth; *B* chrysalis; *C*, larva; *D*, larva of dried-fruit beetle; *E*, pupa; *F*, posterior appendages; *G*, adult beetle. (*A*, *B*, *and C*, *after Chittenden; D*, *E*, *F and G*, *after Essig.*)

Clean Premises.—The packing house should be kept clean, and it is good practice to clean the plant thoroughly at the start of the packing season. Fruit held over from the previous season or refuse fruit must be closely inspected and, if found infested, must be destroyed or fumigated or otherwise treated to eliminate the insects. It is good practice, where the walls are tight enough, to fumigate the plant throughout at the start of the season. Graders, conveyers, etc., must be thoroughly cleansed of webs, pupae, dried fruit, etc. Growers should not allow waste fruit, fruit pits, and fruit refuse to accumulate, because such material is a prolific source of infestation.

The dried-fruit beetle breeds profusely in piles of grape pomace from wineries. If the fresh pomace is spread thinly in the vineyard or orchard so that it will dry quickly there is then little danger of infestation from this source.

Figs left under the trees in the orchard provide excellent breeding places for the dried-fruit beetle.

The raisin moth is the principal cause of infestation of drying or dried fruit on the trays or of the fruit stored temporarily in the open in lug boxes or sweatboxes. Mulberries which ripen and drop from the trees in considerable abundance in the San Joaquin Valley serve as a breeding ground for this and other insects. As this fruit ripens before figs and grapes, it serves as an important intermediate source of infestation. The eggs are laid at night and when exposed to the direct rays of the sun are killed. After the trays have been stacked, however, the fruit is protected from the sun, and eggs deposited at that stage of drying or those deposited in boxes of the dried fruit survive and hatch a good crop of larvae. It has been found by Simmons, Donohoe, and Barnes of the U. S. Department of Agriculture, Bureau of Entomology, Fresno, Calif., and Fisher of the California Dried Fruit Association that covering the stacked trays and boxed dried fruit with shade cloth, such as that used for tobacco, very greatly reduces the crop of larvae by excluding the egg-laying moths.

Figs should not be allowed to lie on the ground after they have fallen from the trees, because they soon become infested with dried-fruit beetles which enter the fruit through the eye in the blossom end.

Fumigation.—Fumigation thoroughly applied kills the insects in all stages of development, including the eggs, and does not injure the flavor, color, or texture of the fruit but requires experience and great care. Carbon bisulfide and hydrocyanic acid gas were formerly the two fumigants generally used. The former is very inflammable and the latter deadly poisonous. They are being replaced with less dangerous fumigants. A satisfactory fumigant should be penetrating, nonexplosive and not costly and should not react with moisture or leave a poisonous residue.

Carbon Bisulfide.—For general purposes in either large or small spaces, carbon bisulfide should be used at the rate of 20 lb.[1] per 1,000 cu. ft. of air space. In handling this material, it must be remembered that the gas is heavier than air and will settle to the bottom of a room or house. This is a great advantage in fumigating heavy dense masses, like raisins and bins and boxes of fruit, for if the carbon bisulfide is placed in shallow containers upon the top, it will gradually work its way through to the bottom. Where the containers for the liquid cannot be placed directly

[1] A pint of carbon bisulfide weighs about 1.3 lb. It would therefore require about 2 gal. per 1,000 cu. ft.

upon the fruit or where fumigation is used in a large house, the containers may be placed on boxes, stepladders, etc., in order to raise them as far above the floor as possible. The *liquid is highly inflammable and the gas is explosive when mixed with air.* Therefore, great care should be taken in keeping flames away from buildings in which carbon bisulfide is used as a fumigant. Where fire insurance is involved, it is advisable to obtain from fire underwriters the rules governing the use of inflammable fumigants.

Hydrocyanic Acid Gas.—In the past this gas has usually been obtained by the pot-generating method, but the liquefied gas in cylinders is more convenient. This fumigant should be handled only by experienced persons because of its intensely poisonous nature. There is some evidence to indicate that the fruit may retain a considerable proportion of the hydrocyanic acid gas, another reason for advising against its use. It has been replaced in California by other fumigants, notably methyl bromide.

Vacuum Fumigation.—Considerable experimentation has been done in recent years by the federal and state authorities with a vacuum fumigator constructed of steel boiler plate and used as a fumigating chamber from which the air is drawn and vacuum conditions created. Into this space the fumigants are drawn and come in intimate contact with the materials placed inside for treatment.

The advantages of such an apparatus include thorough penetration of the vapors into the densest food materials, rapidity of action, and safety of operation. It can be applied to packed as well as to bulk goods.

The product is generally treated in the gas for 1 hr.

Although carbon bisulfide is the fumigant generally used, it may be replaced with hydrocyanic acid gas, with ethyl formate, with carbon bisulfide and carbon dioxide mixture, or with sulfur dioxide. Vacuum fumigation was adopted by most of the large packers of dried vegetables as the most convenient and most dependable method of destroying insects in the packed products (during the World War period and shortly thereafter).

Methyl Bromide.—This fumigant has come into general use recently owing to its effectiveness and its relatively nonexplosive character. It is extremely toxic to insects. It is, unfortunately, also toxic to man. However, it is supplied in liquefied form in cylinders and may be piped to the fumigation chamber, thus reducing the danger to workmen. Small cylinders of the liquefied gas may be opened in the fumigation chamber safely if a mask is worn or if the operator avoids breathing the fumes. It is liberated near the top of the chamber as the gas is heavier than air.

The usual dosage is 1 lb. per 1,000 cu. ft. One large packer stores 5,000 tons of dry fruit, which is fumigated with methyl bromide frequently in order to prevent infestation.

Methyl bromide appears to leave no poisonous residue in the treated fruit. In addition to its efficiency in exterminating insects, it is also extremely effective in destroying rodents in dried-fruit warehouses.

Ethylene Dichloride and Carbon Tetrachloride Mixture.—This mixture is noninflammable and nonexplosive. It leaves no poisonous residue in the treated fruit. It has an anesthetic effect on man but is not particularly irritating to the eyes or respiratory organs. The dosage is 15 to 20 lb. per 1,000 cu. ft. of fruit and space. It is much less toxic than methyl bromide to insects; but is fairly effective if the fumigating chamber is reasonably gastight. It is, however, considered considerably less effective than methyl bromide. Artificial heating or use of burlap sacks as wicking is usually necessary for effective evaporation to form a vapor, as these substances are liquids at ordinary temperatures.

Ethylene Oxide and Ethylene Dichloride Mixture.—A mixture of about 25 per cent of liquid ethylene oxide and 75 per cent liquid ethylene dichloride is often used as a fumigant for boxed dried fruit. About 10 cc. of the mixture is added to each 25-lb. box of the fruit just before sealing. This fumigant is only slightly toxic to man. Prolonged breathing of the fumes may anesthetize or may cause vomiting. It is not so good a fumigant as methyl bromide for use in bulk fumigation.

Ethyl Formate.—This volatile liquid is added by some packers to the boxed dried fruit at the rate of about 5 cc. per 25-lb. box.

Chloropicrin.—This is the familiar tear gas of war days and is known also by the names nitrochloroform and nitrotrichloromethane. It is poured on folded burlap bags on trays in the fumigating chamber; or the workman may spray it from a small pressure cylinder if he wears a protective mask.

The gas is extremely irritating to the eyes and mucous membrane, hence it declares its presence in no uncertain manner. Consequently serious injury from its use is uncommon. It is nonexplosive. The dosage is 1 lb. per 1,000 cu. ft.

Dried fruits should be delivered by the grower to the packer as soon as possible after removal from the trays, as the packer has facilities for fumigating the fruit to kill insects and eggs. If it is necessary to store dried fruit for several months on the farm, some provision for fumigation with some effective fumigant should be made. Chloropicrin is satisfactory.

Sulfur Dioxide.—Apricots during the packing process are wet with water and are treated 4 to 12 hr. in the fumes of burning sulfur. Parker found that this treatment destroyed all insect life on the fruit fumigated in bulk. It may be used for all fruits that are sold in the sulfured condition such as apples, sulfur-bleached raisins, sulfured apricots, peaches, pears, and sulfured Adriatic variety figs. It is inexpensive, simple, and easily applied.

Fumigation of Figs.—Figs are allowed to partially dry on the tree and drop to the ground naturally. Many become infested with fig beetles. Therefore, it is recommended that this fruit be fumigated before placing on trays and again on removal from the dry-yard trays.

Fumigating Chambers.—For fumigating figs, raisins, and other fruits on the farm, tight, small outdoor houses similar to sulfur houses may be constructed. Refrigerator (icebox) type doors should be used. If of wood, the construction should be of double thickness of tongue and groove lumber with building paper between the walls or used as a lining. A simple, inexpensive fumigating hood, a rectangular box large enough to cover a stack of trays, may be built of rubberoid roofing paper over a light wooden frame. Storage bins indoors, also, may be enclosed, but in such cases only nonexplosive, noninflammable fumigants should be used.

The principal requirement is that the chamber be as nearly gastight as possible. Otherwise the fumes, gas, or vapor soon leak out of the chamber, and the insects and eggs are not killed.

The chamber should be provided with a vent to the outside atmosphere, that may be opened when fumigation is complete.

Dosage.—The dosage is usually expressed in pounds of fumigant per 1,000 cu. ft. of fumigation chamber space. The "space" includes that occupied by the fruit, as well as the unoccupied space. For a rectangular chamber the space is calculated very simply as follows: volume in cubic feet equals length × width × height in feet.

Screening-out Insects.—Many of the insect larvae in raisins may be screened out on vibrating screens of large enough mesh to pass the larvae and small enough to retain the raisins. However, this is rather a makeshift and not very commendable procedure. Infestation should be prevented insofar as possible.

Insect-damaged fruits can be detected readily by the methods devised by Howard of the U. S. Department of Agriculture, by Fisher of the Dried Fruit Association, and by others (see section at end of this chapter).

Heat as an Insecticide.—In the processing of prunes, "practically peeled" dried peaches, seeded raisins, and dried figs, the fruits are passed through boiling water or dilute solutions of salt or sodium bicarbonate. The fruits are thoroughly cleansed and all insect life killed by heat.

Several packing houses treat dehydrated vegetables by dry heat for several hours at 145 to 150°F., a treatment found convenient and very effective. The dry heat process may be made continuous by use of superimposed screen conveyers placed in a chamber heated by steam coils, gas, a current of heated air. Any good dehydrater can be used for the purpose. A temperature of 180°F. can be used for products not injured at this temperature and the time of treatment shortened to a few minutes.

Products sterilized by heat must be packed immediately to avoid reinfestation, unless stored in an insectproof room. The containers, also must be sterilized, as they may contain insect eggs.

Insectproof Packing Rooms.—Packing rooms should be of tight construction, so that they may be fumigated occasionally. Doors and windows must be screened to exclude insects. If these precautions are taken, much insect infestation in packed goods may be avoided.

Insectproof Packages.—Tin cans, either friction top or hermetically sealed, are proof against insects and are ideal containers for fruits and vegetables shipped to or through the tropics, or to warm, humid districts, such as the southern United States. They have not been generally adopted because of their relatively high cost and because the public is accustomed to purchasing dried products in paper cartons or boxes and is slow to become accustomed to new styles of containers. However, they deserve greater popularity.

Parker has found that the usual dried-fruit boxes and cartons are not proof against insects. He has, however, developed a process of wrapping small cartons (1- to 10-lb. sizes) in wax paper, as is done with cereal cartons, to exclude some insects effectively. Inner liners, as well as outside wrappers, of aluminum foil are very effective and are in use. Sealed packages also reduce the tendency of dried fruits to lose moisture and become sugary on the surface and prevent excessive absorption of moisture by dried vegetables. Fruit beetles and grain beetles often gnaw holes through such packages, thus gaining entrance. Some insects will penetrate metal foil in this manner.

Fruit which is treated in boiling water or steam before packing must be allowed to dry on the surface before being placed in wrapped cartons, otherwise molding may occur.

Effect of Cold Storage on Insects.—It has been found by De Ong of the University of California that the development of insects is prevented if dried fruits are placed in ordinary commercial cold-storage warehouses at 36 to 50°F. The insects remain dormant but are not killed unless the storage is prolonged 3 to 4 months. This means of storage is used extensively during the summer months in large distributing centers, such as New York and Chicago.

PACKING DRIED APPLES

Dried apples are usually packed by those who dry them and in the same building in which the drier is located.

Grading.—Five grades are generally recognized in the trade, as follows:

Extra Fancy.—Rings of fairly uniform size; uniform white color; clean; free from skins, cores, stems, bruised or rotten spots, worm holes, or screenings.

Fancy.—Rings of fairly uniform size; uniform white or very light yellow color; clean; almost free from skins, cores, stems, bruised spots, worm holes, or screenings.

Extra Choice.—Rings of fairly uniform size; white or light-yellow color; not more than 25 per cent of pieces showing skins, cores, stems, bruised or rotten spots, or worm holes; fairly free from screenings.

Choice.—Rings of white, yellow, or light-brown color; not more than 50 per cent of pieces showing skins, cores, stems, bruised spots, or worm holes; may contain a noticeable amount of screenings.

Standard.—Brown color; large percentage of pieces showing skins, cores, stems, or bruised spots and considerable screenings present.

According to Beattie and Gould only three grades are recognized in some apple drying districts. These grades are Fancy, Choice, and Prime. Fancy corresponds to Extra Fancy in the above list, Choice to Fancy and Prime corresponds to Choice. The fruit not suitable for the Prime grade is cull or substandard and should be used only for by-products.

Curing and Processing.—Dried apples are stored in bins or heaps on the floor and are generally shoveled over several times during curing. It is customary in many plants to overdry the apples slightly and to return water in the pile by sprinkling and shoveling over. Unless the addition of water is carefully controlled by frequent analyses, there is danger of addition of so much water that the apples will spoil in the package or will exceed the government standard of 24 per cent for moisture content.

The moisture content can be determined fairly accurately by drying a 10-gram sample for exactly 4 hr. at 200 to 212°F., (92 to 100°C.) in a water-jacketed oven, although the official method consists in drying a 10-gram sample *in vacuo* at 29 in. mercury and 70°C. (158°F.) for exactly 12 hr. It is customary in most packing plants to expose the processed dried apples to the fumes of burning sulfur for 30 to 60 min. before packing. Mrak of this laboratory finds that dipping the fruit in dilute metabisulfite before drying renders resulfuring unnecessary at the time of packing.

Packing.—Dried apples are in suitable condition for packing when they have passed through the curing period and the individual pieces have all become pliable and have acquired a uniform moisture content. This is determined by their appearance and texture.

Dried apples are usually marketed in 50-lb. boxes. The side of the box intended for the top is packed first, as in the packing of fresh fruit in barrels, and the pieces for the first layer are therefore carefully selected perfect rings. They are faced very carefully with the rings overlapping each other in rows lengthwise of the box on a lining of paraffined paper. After facing, the box is filled, the contents being firmly packed in with a press made for the purpose, and the box is weighed to insure full

measure. The cover (which then becomes the bottom) is nailed on.

Cubed Apples.—Cubed apples are generally packed in 8- or 16-oz. insectproof cardboard cartons.

PACKING DRIED APRICOTS

The process of preparing dried apricots for packing is very simple, and elaborate equipment is not necessary or generally used.

Receiving and Sweating.—The apricots are delivered to the packing house in sacks or in lug boxes and are then stored in large bins to undergo equalization of moisture and to await final processing and packing.

In California the grower's fruit is often sampled as received, and he is paid according to the quality and size of the fruit. The fruit should not contain more than 15 to 16 per cent moisture on delivery.

Quality Grades.—In the packing houses of the Prune and Apricot Growers' Association of California, five quality grades are made. These are: Sunsweet quality, which is the best fruit only; Growers' Brand, sound fruit of good quality free from black or other off-quality specimens; Number One Slabs, equal to Growers' or Sunsweet quality in color and flavor, but flat and thin because of overripeness; Number Two Slabs, slabs which may contain specimens of off-color; and finally culls, including all unmerchantable fruit.

Size Grading.—Apricots are often size graded before storage, because the fruit then moves freely on the screens and is not matted.

The grader consists of a long vibrating screen made up of sections with holes of different diameters. The grader is very similar in appearance to that used for peeled peaches and shown in Fig. 12. The following size grades are made.

1. Extra Fancy, over $^{48}/_{32}$ in. in diameter.
2. Fancy, $^{48}/_{32}$ in. in diameter.
3. Extra Choice, $^{40}/_{32}$ in. in diameter.
4. Choice, $^{32}/_{32}$ in. in diameter.
5. Standard, below $^{32}/_{32}$ in. in diameter.

These size grades apply to both Sunsweet and Growers' Brand qualities of apricots.

The graded fruit falls into portable boxes or large wheelbarrows, in which they are transferred to the storage bins or to the processor.

Processing.—The fruit passes first over a vibrating screen to remove leaves, stems, and other refuse and to break up lumps of matted fruit; then through a small tank of cold water to remove dust, to wet the fruit to facilitate absorption of sulfur fumes, and to render the pieces more pliable.

They then pass beneath sprays of water on a vibrating screen and pass over the end of the screen to 6- by 3-ft. wooden trays. The fruit is spread 2 to 3 in. deep on the trays, and the trays are stacked in staggered position on a car. In processing, 10 to 12 per cent moisture is absorbed.

Sulfuring.—The trays of fruit are placed in sulfur houses and allowed to remain in the fumes of burning sulfur overnight for the purpose of destroying insect eggs and of impregnating the fruit with enough sulfurous acid to prevent darkening of color and fermentation or molding in the final packages.

Boxing and Pressing.—The fruit is generally packed in 25- and 50-pound boxes, from an overhead storage hopper and spout, and the filled boxes carefully weighed.

The fruit is pressed into the boxes by means of a hand-operated plunger or by means of a continuous, mechanical-pressing device.

Cartons holding 2, 3, and 5 lb. of dried apricots are also being packed in increasing quantities.

Prices According to Grade.—The price paid for dried apricots varies according to size and quality. The following prices were paid recently by the Association. Present prices (1938) are somewhat lower.

Sunset Quality	Cents	Growers' Brand Quality	Cents
Choice	24	Choice	22½
Extra Choice	26	Extra Choice	24½
Fancy	28	Fancy	26½
Extra Fancy	30	First Quality Standards	18
Fancy Moorparks	30	Slabs	20
Extra Fancy Moorparks	33		

PACKING DRIED FIGS

The basic principles and practices of fig packing are similar in the United States and Asia Minor, although in America labor-saving machinery is used to a greater extent.

Grading.—Figs are graded for size by graders similar to those used for apricots. The following sizes are recognized in California:

1. Black Figs (Mission Variety):
   a. Fancy, over $^{34}/_{32}$ in. in diameter.
   b. Choice, $^{34}/_{32}$ in. in diameter.
   c. Standard, $^{28}/_{32}$ in. in diameter.
2. White Figs (Calimyrna and Adriatic):
   a. Fancy, over $^{42}/_{32}$ in. in diameter.
   b. Choice, $^{42}/_{32}$ in. in diameter.
   c. Standard, $^{34}/_{32}$ in. in diameter.

Grading is done as soon as the figs are received at the packing house and before binning and storage.

Dipping.—Before packing, figs are treated in a boiling dilute salt solution. Parker gives the following formula for the usual fig dipping

solution: salt, 50 lb.; soda ($NaHCO_3$), 3 to 4 lb.; and water, 150 gal. The figs are carried through the boiling solution on a conveyer in perforated sheet-metal buckets, the usual time of immersion being 45 to 90 sec., depending upon the water content of the figs and the variety.

Dipping destroys insect life, softens the skins, renders the figs pliable, and incidentally increases their weight.

Brick Pack.—The figs are placed before women workers who slit one side of each fig from the stem to the eye with a sharp knife. The fig is then rolled between the thumb and fingers and flattened out in such a manner that the cheeks are spread widely apart and the stem concealed. Spoiled fruit, such as that containing smut, is discarded. The figs are spread to such width that they will fit snugly into small forms made of hard wood and these forms when full are placed beneath a press which compacts the figs into bricks. These are then removed from the forms, wrapped in waxed paper and a lithographed label attached around the brick lengthwise. Uncut Black Mission figs and Calimyrna figs are also packed in bricks and wrapped in cellophane.

The bricks are prepared from Extra Choice and Fancy fruit and are of 4-, 6-, 8-, 12-, and 16-oz. sizes. The best grades are packed in lithographed cartons or wrapped in cellophane.

Bulk Pack.—Figs which are not satisfactory for bricks, fancy carton, or fancy box packs are packed in 25- or 50-lb. boxes for the baking and biscuit trade or are used for fig meats, paste, and a confection base.

Fig Paste.—Much of the dried fig crop of California is converted into paste for use in fig "newtons" (fig cookies) and other bakery or cracker products and confectionery.

The dried figs, if very hard and dry, are steamed or heated a short time in boiling water to soften them. If the figs are too soft to grind, they are spread on trays and dehydrated to remove excess moisture.

They are sliced by machine and sorted on a broad belt to remove figs showing black mold, souring, and insect infestation. Following this, they are washed thoroughly and spread on trays a day or two to dry and to permit sampling and microscopical examination of samples.

The figs are then ground to a paste in a two-stage grinder in which the fruit is forced through $\frac{3}{8}$-in. holes in a grinder plate against revolving blades and through $\frac{1}{8}$-in. holes, also against a revolving knife.

The paste is bulk packed for the confectionery and baking trades; very little enters the retail trade in its original condition.

At present fig paste is the principal outlet for California figs. It is much in demand in the baking and cracker industries.

Fancy Packs.—Much of the large fruit is used for special packs. The figs immediately after dipping are carefully inspected for smut and insect damage; and they are then "pulled," *i.e.*, manipulated with the hands until soft and pliable and formed into the desired shapes.

Circular boxes are often used as containers, the figs being packed in concentric rings. Usually the surface layer of such packs consists of black and white figs arranged in an attractive pattern.

Layer raisins, peeled dried peaches, nuts, and figs are employed in making up "Christmas boxes" holding about 10 lb. each.

Packing Imported Figs.—Considerable quantities of figs from Mediterranean countries are imported to the United States and packed in New York and other large cities.

Fig "Smut."—The white varieties of dried figs, Smyrna (Calimyrna) and Adriatic, sometimes contain a profuse growth of black mold spores. Infection occurs in the orchard, and most of the growth probably occurs before the fruit reaches the packing house. It is practically impossible to identify figs containing this mold unless the figs are cut or torn open. The Mission fig is not affected by the sooty mold, probably because its "eye" is sealed against entrance of the organism. Most white figs are cut open as described on page 525 before packing, to permit removal of moldy figs.

PACKING DRIED PEACHES

Sun-dried peaches are packed in two forms: unpeeled and "practically peeled." In California much of the dried peach crop is packed by the California Peach and Fig Growers' Association, a cooperative organization with headquarters at Fresno.

Grading and Storing.—The peaches are graded for size on mechanical graders, as described elsewhere for apricots, and the grower is paid according to the amounts of each size delivered. The size grades are:

1. Extra Fancy, over $\frac{58}{32}$ in. in diameter.
2. Fancy, $\frac{58}{32}$ in. in diameter.
3. Extra Choice, $\frac{50}{32}$ in. in diameter.
4. Choice, $\frac{42}{32}$ in. in diameter.
5. Standard, $\frac{34}{32}$ in. in diameter.

Dried peaches are divided into two general classes, namely "Muirs" and "Yellows," the latter term including several yellow-fleshed freestone varieties, principally the Lovell and Elberta. The Muir peach is preferred to other varieties on account of its color, flavor, and sweetness.

The graded peaches are stored in bins until they are to be packed. The moisture content at the time of binning should not exceed 16 per cent, in order that matting and crushing of the fruit may not occur.

Fumigating.—Fumigation of the dried fruit is desirable if it is to be stored several months before packing.

Packing Unpeeled Peaches.—Unpeeled peaches are processed and packed in the same manner as described elsewhere for apricots.

"Practically Peeled" Peaches.—This process was developed by W. H. Beekhius, formerly factory manager of the Peach and Fig Growers' Association and now field manager of the Dried Fruit Association.

The dried peaches are carried on a metal conveyer through a boiling, approximately 20 per cent, sodium bicarbonate solution, which loosens the skins. They then pass through a screen cylinder in which revolve stiff-bristled spiral-shaped brushes. These brushes rub the peaches against the screen and thus remove the loosened peels; and sprays of water wash the peels and adhering soda solution through the screen to the waste drain. This process removes most of the peel from the ripe fruit, but unripe peaches do not peel satisfactorily.

The "practically peeled" fruit next passes by means of a conveyer through a tunnel dryer heated by steam coils. This removes excess surface moisture, which would otherwise cause molding or fermentation in the packages or would cause the packages, because of drying, after a few weeks' storage to contain a much lower net weight of fruit than is placed in them at the time of packing.

The peaches are spread on trays and sulfured, usually overnight. They are packed in attractively lithographed cartons holding 1, 2, and 5 lb. each.

PACKING DRIED PEARS

Dried pears, because of the heavy sulfuring given them before drying and because they are removed from the trays while still pliable, usually require no processing in water or sulfuring before packing.

Grades.—In a large dry yard and packing house in central California the pears are graded for size and quality by women who stand before a slowly moving belt. The grades made in this plant are Jumbo (largest and finest fruit), Extra Fancy, and Northern California pears. The three best grades are packed as Lake County pears. In another packing house the following grades are made: Extra Fancy, Fancy, Extra Choice, Choice, and Standard. Great care must be taken to remove fruit that shows insect damage. Such damage is usually done by codling moth larvae to the fruit before picking or during ripening after picking.

Packing.—The sorted fruit is packed in 10-, 25-, and 50-lb. boxes. Overdried fruit is processed before packing, as described elsewhere for apricots.

PACKING DRIED PRUNES

The processing, grading, and packing of prunes is a specialized industry, separate and distinct from the growing and drying industry. While

the varieties of prunes are different in the two regions, the methods followed in the commercial packing of prunes in the Pacific northwest and in California are very similar.

Receiving and Door Test.—The prunes are generally allowed to undergo sweating in bins or boxes at the dry yard or drier before delivery to the packing house.

In most packing houses each load of prunes as delivered is sampled carefully, their quality determined, and the number of prunes per pound determined. This is known as the "door test," on the basis of which packing houses pay the grower.

Grading.—Each lot is size-graded, in most packing houses immediately after delivery, and the weights of prunes falling into the different size grades are determined. A grader similar to that used for peaches for canning and equipped with vibrating screens with circular openings is used for grading. Immediately beneath each screen is a bin; thus prunes of "40 to 50" size fall into one bin, "30 to 40's," etc., into other bins. The graded prunes are transferred to large wheelbarrows or trucks for weighing and are transported to storage bins. The usual size grades and corresponding diameters of screen openings are given in Table 76.

Before entering the grader the prunes pass over a vibrating screen which removes loose dirt, leaves, stems, etc.

TABLE 76.—SIZE GRADES FOR DRIED PRUNES IN CALIFORNIA
(*After Cruess and Christie's "Laboratory Manual of Fruit and Vegetable Products"*)

Number of prunes per pound	Diameter of grader holes, inches
20 to 30	$\frac{42}{32}$
30 to 40	$\frac{40}{32}$
40 to 50	$\frac{38}{32}$
50 to 60	$\frac{36}{32}$
60 to 70	$\frac{33}{32}$
70 to 80	$\frac{32}{32}$
80 to 90	$\frac{30}{32}$
90 to 100	$\frac{28}{32}$
100 to 110	$\frac{26}{32}$
110 to 120	$\frac{24}{32}$
120 and up	below $\frac{24}{32}$

Processing.—The processing of dried prunes consists in immersing them in hot water for a period of 2 min. or more in a processor which consists of a long metal tank filled with water heated to boiling or nearly

to boiling by steam coils or open-steam jets and of a conveyer equipped with perforated sheet-metal buckets.

Processing cleanses the fruit, destroys all insect life, and renders the prunes soft, pliable, and of glossy appearance. The fruit increases in weight about 6 to 8 per cent through absorption of water.

Packing and Cooling.—The prunes are packed directly from the processor without drying or cooling, 25- and 50-lb. boxes lined with paper being the usual containers. The hot fruit is filled into the boxes by weight and pressed flush with the top of the box with a hand-lever press or with a continuous dried-fruit press.

The boxes retain a high temperature for several hours if packed closely together, resulting in caramelization of the sugars in the fruit and in severe injury to quality. The boxes are therefore stacked in staggered fashion so that air currents may pass freely between them and cool them quickly.

Cartons holding 1, 2, 3, 5, and 10 lb. of prunes are now used rather extensively. They are of convenient size for the average family and usually insure that the prunes reach the consumer in good condition.

Canning.—Prunes, to some extent, are packed scalding hot in cans and sealed under a high vacuum. When packed in this manner, they preserve their original glossy appearance and soft texture and do not undergo "sugaring." They are also packed hot into cans and exhausted in live steam for 15 min. before sealing. Unless vacuum sealed or thoroughly exhausted before sealing, corrosion and perforation of the tin plate are very common and spoilage losses from these sources very heavy. Prunes to be eaten out of hand as a confection should be blanched in boiling water until they contain about 32 to 33 per cent moisture. They are canned scalding hot in double enameled Type L cans, exhausted 10 min., sealed, and processed 30 min. in boiling water. This is a very attractive and tasty product.

Prunes are also canned in dilute syrup, in ready-to-serve form. Briefly, size-graded dry prunes are blanched in boiling water 8 to 10 min.; they are canned in Type L cans and a syrup of 20° Brix is added; the cans are exhausted in live steam for 15 min.; then sealed and processed in boiling water 30 to 60 min.

Pitted Prunes.—Small prunes, sizes smaller than 100 to the pound, are now used for the preparation of pitted prunes sold to the baking trade in 25-lb. boxes. They are excellent for fruit cakes, plum puddings, and pies and can be used in bread as a substitute for raisins.

The prunes are first treated 6 to 7 min. in boiling water, or preferably a longer time in live steam, then spread on trays which are stacked and allowed to stand overnight to permit the prunes to soften, after which they are dried a short time to remove surface moisture in order to prevent

sticking of the fruit to the pitting machine. They are pitted by a machine similar to that used for seeding raisins (see Fig. 92).

Packing Artificially Dried Prunes.—Dehydrated prunes in Oregon and California are packed in a manner very similar to that described for

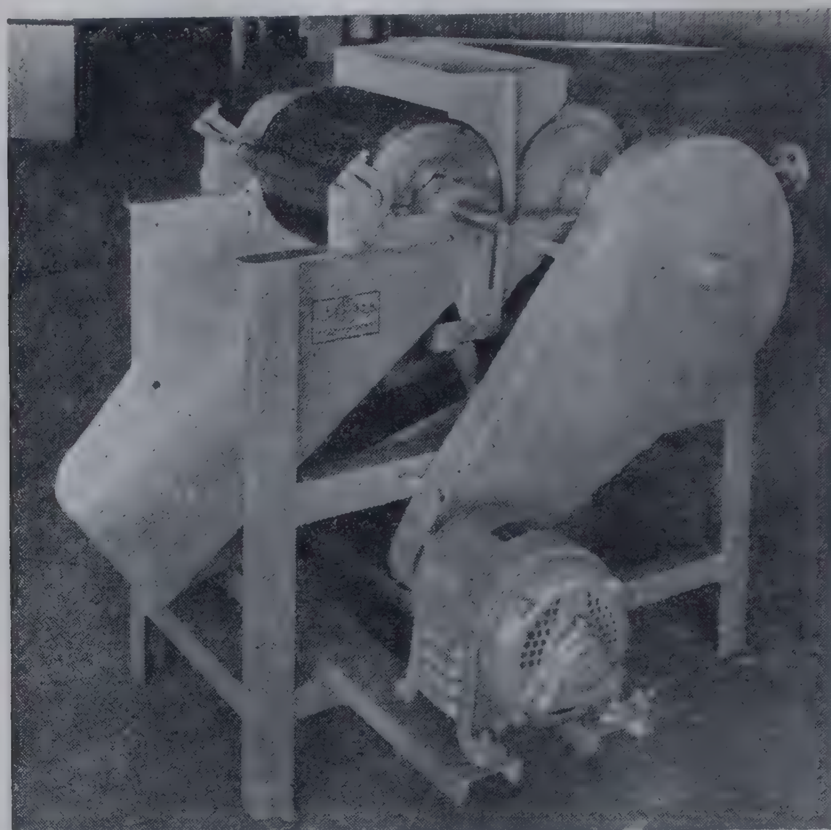

FIG. 92.—Seeder for prunes, olives, and dates. (*Courtesy of Elliott Manufacturing Company*

California sun-dried prunes. Generally, however, the Oregon prunes are processed in steam rather than in boiling water.

TABLE 77.—RELATIVE RATES OF ABSORPTION OF MOISTURE BY PRUNES PROCESSED IN BOILING WATER AND IN STEAM
(*After Christie*)

Lot No.	Moisture, per cent in original prunes	Percentage of moisture							
		Minutes in hot water			Minutes in steam				
		2	4	6	2	4	6	8	10
1	17.3	.....	.....	.....	20.3	20.7	21.5	22.4	23.3
2	21.4	23.0	24.9	28.6*	....	22.9	....	24.2	
3	21.9	24.1	26.9†	30.7*	22.9	23.3	23.9	24.5	25.9
4	21.6	28.3†	29.5*	31.3*	23.9	25.2	25.6	26.1	27.0†
5	21.5	24.9	26.8†	27.8*	23.0	23.2	24.0	25.0	25.1
6	16.8	21.0	23.0	25.0	18.6	20.0	20.3	21.1	21.5

* Very moldy. † Trace of mold.

The same size grades prevail in Oregon as in California.

Christie processed six different lots of dehydrated prunes in water and steam to obtain data on the relative rates of moisture absorption in the two media, as shown in Table 77.

Storage tests showed that prunes of a moisture content of 28.6 to 30.7 per cent became moldy and that those of 25 per cent moisture did not mold.

Moisture absorption was more rapid in water than in steam.

PACKING OF RAISINS

The mechanical equipment used in preparing and packing raisins has been brought to a high state of development.

Bulk-packed raisins and most of the carton-packed raisins are handled throughout by machinery; only certain kinds of carton goods and layer raisins are packed by hand.

Receiving.—The raisins are delivered in sweatboxes holding about 175 lb. of raisins each. The raisins are usually sampled and a moisture test made. The packer desires the raisins to contain not more than 16 per cent of moisture, because if the moisture content is excessive it is very difficult to remove the stems. Nichols invented a simple device for measuring the moisture content of raisins by measuring their compressibility under standard conditions. Means are also available for determining the sand content, per cent of moldy raisins, and degree of insect infestation, (see section at end of chapter).

Stemming.—All varieties of raisins are passed through a stemming machine, consisting of a screen cylinder which revolves close to a half cylinder of the same material. The raisins are given a rubbing motion as they pass between the two screens, and the coarse stems are broken from them. The stems in the old-style stemmers are removed by a blast of air, which also removes some of the small and light raisins. In the latest type of stemmer the stems are removed by revolving "combs" which pick up and remove the stems but permit the raisins to pass through to a conveyer which carries them to the grader.

Grading.—Stemmed raisins are graded by means of vibrating screens into the following grades:

1. Loose Muscats (stemmed raisins):
   a. One-crown, $^{13}/_{32}$ in. in diameter.
   b. Two-crown, $^{17}/_{32}$ in. in diameter.
   c. Three-crown, $^{21}/_{32}$ in. in diameter.
   d. Four-crown, over $^{21}/_{32}$ in. in diameter.
2. Seeded Muscats (above sizes seeded).

The seedless raisins are usually graded for size, but the grades are not so clearly defined as for the Muscat raisins. These are classified, accord-

ing to the method used in drying the fresh grapes, as "natural" (not lye dipped or bleached), "bleached" (sulfured before drying), and "soda dipped" (lye or soda dipped before drying).

Layers are classified according to size of the berries and bunches, as Vineyard Run, Three-crown Layers, Four-crown Clusters, and Six-crown or Imperial Clusters. The Three-crown Layers are the smallest and Six-crown, or Imperial, the largest in size.

Drying for Cap Stemming.—Many of the stemmed raisins still retain the "cap" stems (the small stems which attach the berries to the main stem). These must be removed before the raisins are seeded or packed. Muscat raisins cannot be cap stemmed satisfactorily unless they are dried to less than 12 per cent of moisture.

In one of the large driers the raisins are fed mechanically on the topmost woven-wire draper of the drier, which is about 10 ft. wide and about 50 ft. long, and are spread to give a load of about 5 lb. per square foot. The initial temperature on this draper is about 120°F. The draper carries the raisins slowly to the opposite end of the drier and drops them to the draper immediately below. The raisins traverse the length of the drier seven times during drying, the temperature increasing as they progress until they reach a temperature of 165 to 180°F.

Heat is furnished by heated air blown upward through the drapers of raisins by a powerful multivane fan.

The raisins are delivered by the lowermost draper to a cooling draper, on which they are chilled by an upward blast of cold air. This hardens them by increasing the viscosity of the invert sugar syrup in the raisins and gives them sufficient rigidity to withstand cap stemming. The drying time is about 5 hr.

Only Muscat, Malaga, and other large varieties of raisins require the drying process described above. Thompson Seedless and Sultana varieties can be cap stemmed without such drying.

Cap Stemming.—The cap stemmer consists of two concentric truncated cones made of heavy screen. One cone revolves rapidly, and the distance between the cones is such that the raisins are rolled and rubbed vigorously to remove the stems. The cap-stemmed raisins pass over a screen and through a blast of air to separate them from the dislodged cap stems.

Seedless raisins are sprinkled with water as they enter the cap stemmer.

Floating.—The one-crown, *i.e.*, smallest size Muscat raisins, are not seeded. They contain, as they come from the stemmer, many light immature dried berries. These immature and worthless raisins are removed by flotation in water.

Seeding.—The larger sizes of cap-stemmed Muscat raisins are generally seeded. The raisins are first treated in water (at about 200°F.)

and steam to soften them and to return the moisture removed in drying for cap stemming. The processor consists of a tank of heated water in which revolves a screen cylinder which carries the raisins through the water. The heating loosens the seeds and softens the pulp so that the seeds can be removed readily.

The seeder is equipped with four rolls. Two of these are of rubber, one is made up of very fine-toothed circular saws and one of very coarse circular saws. The fine saws are known as the "seeder rolls" and the coarse saws as the "flicker rolls." The rubber rolls press the raisins against the revolving fine-toothed circular saws (the seeder rolls). The flesh of the raisins is pressed into the saw teeth. The seeds remain on top of the saws and are removed by the coarse saws. Rubber rolls next force the raisins between metal fingers so adjusted that the soft raisins pass between them and the hard seeds are caught and removed. Fourteen seeders handle the output of 10 continuous driers, or approximately 40 tons of raisins per hour.

Seeding has greatly increased the popularity of Muscat raisins and has made their use in baking, confectionery, ice cream, and in general cookery possible. In the Raisin Association's plant most of the seeded Muscat raisins are treated by a secret process with highly refined raisin seed oil to prevent sticking of the raisins together—a very successful treatment.

Packing.—The hot seeded Muscat raisins direct from the seeder are packed by women into 12- and 15-oz. cartons or into boxes holding 25 and 50 lb. Fiberboard cartons are now very generally used as containers for raisins for the baking trade and other users of bulk raisins. These containers are lined with heavy waxed paper which retards evaporation and thereby reduces the tendency for these raisins to "sugar" during storage.

The Thompson Seedless (Sultanina) raisins and other seedless raisins are packed by automatic machines into small cartons or in bulk boxes. At one time about 15,000 tons annually of the Thompson Seedless raisins were packed and sold in small cartons which retail for 5 cents each; but this pack appears to have lost its former popularity.

Other Packages.—Seeded Muscat raisins were at one time also packed in cans for shipment to the tropics and in this form are proof against spoilage. The recommended process consists in increasing the moisture content of the seeded raisins to 30 per cent, canning, exhausting 15 min. at 200 to 212°F., sealing, sterilizing at 212°F. for 25 min. and cooling. The 8- and 12-oz. cans are preferred.

Layer raisins are packed very carefully into shallow cartons for dessert use. They are also frequently used in fancy mixed packs of

raisins, nuts, figs and peaches for the holiday trade (see paragraph on "grading" for different grades of layer raisins).

Fumigation.—Seedless raisins are not heated before packing and hence should be fumigated, in the final insectproof package as well as before processing.

The seeded Muscat is not so liable to infestation because it is sterilized effectively by heat during drying for cap stemming and again during the seeding process.

PACKING DEHYDRATED VEGETABLES

During the World War it became necessary to develop methods of packing which would protect dehydrated vegetables against insects and moisture.

Effect of Moisture.—Vegetables must be dried to a low moisture content, and the package must protect them against absorption of moisture, otherwise the vegetables discolor and rapidly deteriorate in flavor. Their moisture content should be maintained below 8 per cent.

Dehydrated vegetables, according to Nichols (1920), will undergo molding if the moisture content exceeds 20 per cent.

Packages.—Nichols has found that a tightly sealed carton is satisfactory for storage of dried vegetables in an arid climate but unsuitable for use in a moist climate, because under the latter condition moisture penetrates the package readily, even if paraffined, and increases the moisture content of the vegetables to the point where rapid deterioration ensues. Some of the changes are enzymic, others purely chemical.

Friction top cans were found to be reasonably resistant to moisture absorption and relatively inexpensive and convenient. For use of the U. S. Army, the vegetables were sealed by solder in 5-gal. cans. Cans sealed by double-seaming are satisfactory but more expensive than cartons and less convenient than friction top cans. Vacuum packing has been found to improve the keeping quality of dehydrated vegetables greatly.

Fumigation.—Dried vegetables should always be fumigated or otherwise treated to render them free of insect life. Cartons and boxes must also be fumigated before packing as they may carry insect eggs. Vacuum fumigation of the carton packed product has been used.

Heat Treatment.—Heating to 145 to 160°F. for 2 to 3 hr. will kill the insects and their eggs after packing; or a shorter heating of the dried vegetables on a metal cloth conveyor will suffice.

LABORATORY EXAMINATION OF DRIED FRUITS

Owing to the adoption by the food administration and by packers of rather stringent standards for dried fruits in respect to presence of mold

rot, sand, and insects or insect damage, it has become necessary for packers to make, or have made, certain tests upon the dried fruit as received and upon the packed fruit. Cut fruits (apricots, peaches, pears, and apples), raisins, and fig paste are particularly apt to show insect infestation, insect parts, or other evidence of insect damage.

Sampling Unprocessed Dried Fruit.—Samples of a handful should be taken from several boxes, or several locations in the bin of fruit, including positions several feet beneath the surface, or samples may be taken from the grader or conveyer belt. The samples should be well mixed and an average sample taken for examination.

Moisture.—Some of the sample may be ground in a simple, inexpensive kitchen-size food grinder, first with the bladed knife and then with the nut-butter attachment.

A weighed sample of 4 to 5 grams may be dried in a shallow aluminum dish in a vacuum oven 12 to 14 hr. at 70°C. The loss in weight is moisture. Or the moisture may be determined by determination of conductivity of the sample by a special instrument invented by C. D. Fisher and obtainable through the California Dried Fruit Association, 1 Drumm St., San Francisco. Instructions and tables accompany the instrument. Properly used, it is remarkably accurate and rapid in operation.

Moisture may be determined approximately by distillation of a 50-gram sample with xylene or toluene (see reference to Nichols and Reed).

Drying at 100°C. is subject to serious error owing to decomposition of levulose to carbon dioxide and water at that temperature.

Sand in Raisins.—A sample of 250 grams of the finely ground raisins is thoroughly mixed with 2 qt. of water and boiled several minutes with stirring to break up lumps. The lighter ground-raisin flesh is floated off carefully in a stream of water. Saturated brine is then added, and the material that floats is skimmed off. The residue is "panned," *i.e.*, gently agitated in a shallow pan with the brine until the sand is free of raisin particles. It may then be filtered on an ignited Gooch crucible, dried, ignited, and weighed; or may be measured by volume in a Dried Fruit Association sand tube. The sand content should not exceed 7 units measured in this tube.

Mold and Rot in Raisins.—Two samples of 100 berries each are placed in saucers of 3 per cent hydrogen peroxide. Areas attacked by mold or rot cause evolution of oxygen gas because of the presence of a catalase formed by the mold. Total mold- and insect-damaged raisins should not exceed 10 per cent, or 8 per cent if the sand content is high.

Insect Damage.—For raisins the test consists in rolling a number of individual raisins between the fingers beneath water in a white dish and examining for presence of pellets (excreta) and insects or insect parts.

The rubbing should be severe enough to dislodge pellets or insects that may be present beneath the skin. Often also badly attacked raisins will be evident to the eye or by aid of a hand lens; portions of the skin may be eaten away, or pellets and webbing may be evident.

At least 50 specimens of cut fruit such as peaches, apricots, pears, or nectarines should be examined. Usually insects and insect damage are evident to the unaided eye or with a hand lens. Infestation is of two types, *viz.*, that occurring on the tree from such insects as codling moth and peach twig borer and that occurring during or subsequent to drying. Any piece is classified as infested if insects, dead or alive (larvae, pupae, or adults), or their excreta are present.

Peaches and pears will usually show heavier infestation than apricots owing to attack of the fruit by codling moth (pears) and borer (peaches) on the trees.

Growers should discard wormy fruit and should not dry it. Packers should sort all dried fruit carefully under rather intense light on slowly moving belts in order to remove all or nearly all of the infested pieces. It should be feasible to reduce the number of infested pieces below 3 per cent.

A weighed sample of fig paste may be heated with sodium hydroxide solution to dissolve and remove most of the fruit tissue. Worm and insect heads and other chitinous parts of the insects are not destroyed. They can be identified by examining under a low-power microscope for insect fragments, much as the presence of worm fragments of tomato products is determined. The number of worm or insect heads per standard weight of paste are counted. Details of the test may be had from the Dried Fruit Association, San Francisco or Fresno, Calif., and from the Food and Drug Administration, U. S. Department of Agriculture, Washington, D. C.

Other Determinations.—The total sulfur dioxide content of cut fruits is often determined by distillation of a 50-gram sample, mixed with water and a few cubic centimeters of hydrochloric or phosphoric acid, into standard iodine solution and titrating the excess iodine with N/10 thiosulfate (see Association of Official Agricultural Chemists, "Official and Tentative Methods of Analysis," 1936, for details).

Total sugars and total reducing sugars are determined by the standard gravimetric Munson-Walker method, by the Shaffer-Hartmann, or by other accurate volumetric method.

Other determinations are seldom made.

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CHAPTER XXIV

VINEGAR MANUFACTURE

The manufacture of vinegar provides a means of utilizing a large proportion of the cull fruit from apple packing establishments and the peels and cores from apple dryers and canneries. Other cull fruits, such as oranges, grapes, prunes, peaches, pears, pineapples, bananas, and starchy vegetables, such as sweet potatoes, can also be utilized for vinegar manufacture.

Definitions.—Vinegar may be defined as a condiment made from various sugary and starchy materials by alcoholic and subsequent acetic fermentation.

Cider Vinegar.—The Pure Food and Drug Act of the United States defines cider vinegar or apple vinegar as "the product of alcoholic and subsequent acetous fermentation of the juice of apples." According to the pure food and drug regulations the word "vinegar" unqualified can be applied only to vinegar made from apples. However, the word "vinegar" is derived from the French *vinaigre* (sour wine).

Cider vinegar is levorotatory. It contains at least 4 grams of acetic acid per 100 cc. and at least 1.6 grams of apple solids per 100 cc., of which not more than 50 per cent are reducing sugars. It must be stated, however, that most of the cider vinegar on the market need not conform to these standards for the reason that it is diluted with water and the label on the container bears a statement to that effect. Diluted cider vinegar must contain at least 4 grams of acetic acid per 100 cc. but need not conform to the other standards noted above.

Grape vinegar or wine vinegar is made by the alcoholic and subsequent acetous fermentation of the juice of grapes and must, at 20°C., contain more than 1 gram of grape solids, more than 0.13 gram of grape ash, and at least 4 grams of acetic acid per 100 cc.

Spirit vinegar, distilled vinegar, grain vinegar, is the product made by the acetous fermentation of dilute distilled alcohol and contains, in 100 cc. (20°C.), not less than 4 grams of acetic acid.

Miscellaneous Commercial Vinegars.—In a recent decision by a court in the eastern United States, vinegar made from the dried peels and cores may be labeled "Apple vinegar from dried cores and peels," and the names "cider vinegar" and "apple cider vinegar" are reserved for use in labeling vinegar made from the juice of the whole fresh fruit.

Any fruit which contains more than 9 per cent sugar can be converted into a vinegar which will contain more than the legal minimum of 4 grams acetic acid per 100 cc.

One of the largest sources of distilled vinegar is the waste liquor from the manufacture of compressed yeast. Starchy vegetables are sometimes used in the manufacture of distilled vinegar. This is particularly true in Germany where potatoes are used for this purpose.

Relation of Fruit Vinegars to Horticulture.—Where vinegar is produced on a large scale commercially, as in the case of apple vinegar, this manufacture acts as a balance wheel for the industry by absorbing much of the fruit which would otherwise appear on the market in competition with graded fruit to the disadvantage of the latter.

Uses of Vinegar.—In addition to its use on the table one of the principal commercial uses of vinegar is in the manufacture of pickles. Large quantities are also used in the manufacture of tomato catsup, chili sauce and sauces used in the canning of fish. It is also used in the manufacture of acetic acid and for the production of acetone, a solvent used in the manufacture of smokeless powders.

Preparation of Fresh Fruits.—Juicy fruits, such as apples, grapes, and oranges, are usually crushed and pressed without preliminary fermentation of the crushed fruit before pressing.

Apples are grated and pressed as in the preparation of unfermented cider. The modern hammer-mill-type grinder should be used. The pomace contains a considerable amount of juice, a large proportion of which is recovered by grinding in an apple grater and pressing. A larger yield is obtained by placing the pomace in tanks and permitting it to ferment for 2 or 3 days before pressing. If this method is employed, 10 to 20 gal. of actively fermenting cider per ton of pomace must be added and mixed with the pomace in order to promote yeast fermentation and prevent acetification. If the pomace or other raw material acetifies (becomes vinegar sour), the acetic acid will in many cases stop alcoholic fermentation and result in a partially fermented inferior vinegar. The juice expressed from the pomace should not be mixed with the juice from the whole apples because it is inferior in quality.

Grapes are crushed and pressed as for making white juice.

Cull oranges once were used in a large factory in California for vinegar manufacture. The process formerly in use was developed by Chace and Poore of the Citrus By-products Laboratory of the Bureau of Chemistry, U. S. Department of Agriculture, in Los Angeles, Calif. The juice was expressed with large, fluted, bronze rolls. The fresh juice containing the orange oil from the skins was centrifuged for recovery of the oil and the juice then was used for vinegar making.

Pears, peaches, apricots, fresh prunes, plums, ripe bananas, and other pulpy fruits should first be crushed and allowed to undergo alcoholic fermentation for several days before pressing, since preliminary fermentation facilitates pressing and increases the yield.

Dried Fruits.—Dried fruits contain from 50 to 70 per cent sugar. Enough water should be added to reduce the sugar content of the mixture to about 15 per cent, a starter of pure yeast added, and the mixture allowed to ferment until well disintegrated before pressing. The pressed juice may then be allowed to ferment dry and later acetified in the usual manner.

Preparation of Starchy Tubers, Etc.—Starchy vegetables, such as potatoes, must be hydrolyzed with diastase or with dilute mineral acids before fermentation. The crushed vegetables are heated under pressure in a closed retort, or more slowly by boiling in water or by steaming at atmospheric pressure to gelatinize or dissolve the starch. The mixture must then be cooled to 60°C. if it is to be hydrolyzed with malt. Two to five per cent of ground malt should be added, mixed with the gelatinized mass and stirred until the starch is converted to maltose by the following reaction (some dextrin also is formed).

$$\underset{\text{starch}}{(C_6H_{10}O_5)x} + \underset{\text{water}}{x(H_2O)} = \underset{\text{maltose}}{x(C_{12}H_{22}O_{11})}$$

This process is known as "mashing" and the vessel in which the process is conducted, the "mash tun." It consists of a large, circular tank equipped with a stirring device and open steam coils.

The progress of hydrolysis is observed by testing with iodine solutions as follows: A drop of the mash is placed in a dish and a drop of dilute iodine solution is added. If starch is still present, a deep blue color is obtained.

Sweet potatoes normally contain 25 to 30 per cent total carbohydrates, of which starch forms the major proportion, and Irish potatoes usually contain from 16 to 22 per cent starch. Sweet potatoes produce a palatable vinegar without distillation, but because of the disagreeable flavor of fermented Irish potatoes, vinegar is made from the alcoholic distillate of the fermented material.

The gelatinized starch may also be converted to fermentable sugar, in this case dextrose, by treatment in retorts under steam pressure with a dilute mineral acid, such as hydrochloric and the acid neutralized with sodium carbonate, calcium carbonate, or sodium hydroxide after hydrolysis.

Honey.—Low-grade honey unsuitable for table use may be utilized for making vinegar. The honey is diluted to about 15° Balling. Yeast food must be added in order to secure satisfactory fermentation. In

this laboratory approximately 2 grams of potassium dihydrogen phosphate, 2 grams of ammonium sulfate, and 3 grams of citric acid per liter gave good fermentation.

Fermentation.—The manufacture of vinegar requires two fermentation processes. The first of these is fermentation of the sugars to alcohol and carbon dioxide and is accomplished by yeast. The second fermentation results in the oxidation of the alcohol to acetic acid and is caused by vinegar bacteria. The reactions involved are shown by the following equations:

$$C_6H_{12}O_6 = 2CO_2 + 2C_2H_5OH$$
$$2C_2H_5OH + 2O_2 = 2CH_3CO_2H + 2H_2O$$

An intermediate step in acetification is the formation of acetaldehyde by the following reaction:

$$2C_2H_5OH + O_2 = 2CH_3CH{:}O + 2H_2O$$

Effect of Acetic Acid on Yeast.—The two fermentations, alcoholic and acetic, cannot continue simultaneously for the reason that the acetic acid formed by the vinegar bacteria retards yeast growth and activity. Experiments made by the writer prove that *Saccharomyces ellipsoideus* ceases growth and fermentation, if the acetic acid concentration exceeds 0.5 per cent. This amount of acid is often formed in the commercial manufacture of vinegar from waste fruits before alcoholic fermentation where unsound material is used and pure yeast is not added. "Stuck" tanks, those in which alcoholic fermentation has ceased before fermentation is complete, are common on this account.

Vinegar bacteria themselves are not necessarily injurious to the growth of yeast; it is only the product of their activity, *viz.*, acetic acid, that is harmful.

Effect of Vinegar Bacteria on Sugar.—Vinegar manufacturers have stated to the writer that sugar remaining in "stuck" fruit juices will be converted by vinegar bacteria into acetic acid without the intervening step of alcoholic fermentation but experiments have proved that such is not the case.

Wild Yeasts.—Various forms of wild yeast are very troublesome in the fermentation of fruit juices. Most of these have been described in Chap. I, but brief reference may be made at this time to their relation to vinegar manufacture.

Hansenia Apiculata.—This is a wild yeast that is present in practically every spontaneous fermentation of fruit juice. It develops very rapidly in the juice and consumes a large proportion of the nonsaccharine yeast foods, reducing these substances to such a degree that the true yeast which develops later finds it very difficult to multiply. It is also thought that

H. apiculata excretes substances that are poisonous to the true yeasts. For example, it forms acetic acid which is deleterious to true yeast activity. It forms very small amounts of alcohol and is very inefficient in its alcoholic fermentation, *i.e.*, only a small proportion of the sugar destroyed by this yeast is converted into alcohol. In samples examined by the writer, the apiculatus yeast outnumbered the true yeast in fresh apple juice, and in many samples the ratio was 1,000,000 of apiculatus cells per cubic centimeter to 100 or less of the true yeast *Saccharomyces ellipsoideus*. It may be controlled in the fermentation of fruit juices by the addition of a large starter of pure yeast in the manner to be described later.

Mycoderma.—Another wild yeast of common occurrence and one which is very objectionable in the preparation of fruit vinegar is Mycoderma, commonly known as "wine flowers." There are, however, other film yeasts that are often confused with this organism, and which act in similar manner on alcoholic liquids. It is strongly aerobic and develops on the surface of fermented or fermenting fruit juices or other fermented liquids of alcoholic or sugary nature. Its cultural characteristics have been described in Chap. I. It is characterized by its vigorous oxidation of alcohol, sugars, and organic acids to carbon dioxide and water. Where the organism is grown in pure culture in fermented fruit juice it will, in a few months' time, destroy all the alcohol and will convert such a liquid from an acid to an alkaline reaction. Typical oxidizing reactions caused by this organism are the following:

$$6O_2 + C_6H_{12}O_6 = 6CO_2 + 6H_2O$$
$$C_2H_5OH + 3O_2 = 2CO_2 + 3H_2O$$

The organism is very common in cider-vinegar factories and develops frequently in the spontaneous fermentation of cider. Normally it develops after the yeast fermentation is complete and before the acetic acid fermentation begins, as a chalky-white, wrinkled film which usually possesses more or less of a fruity ester odor. Its development in fermented liquids can be prevented by the addition of vinegar or by excluding air. If the acetic acid is increased to 1 per cent or more, Mycoderma does not develop rapidly.

Torula.—A third group of wild yeasts of considerable importance in the fermentation of fruit juices is that of the Torula yeasts, which are characterized by rapid growth as sediment yeasts, by low alcohol-forming power, and usually by their spherical appearance under the microscope. They are objectionable in the fermentation of fruit juice for the same reasons as those given for apiculatus yeast. Their growth may be checked by the addition of a pure yeast culture.

Other Wild Yeasts.—There are a number of other yeasts which develop in the fermentation of fruit juices, but these need not be described

in detail at this time. A discussion of most of these organisms will be found in Chap. I.

Desirable Yeasts.—In general it may be stated that the most desirable fermentation of fruit juices and other liquids intended for vinegar manufacture is the one carried out by the so-called "culture" yeasts, such as *Saccharomyces ellipsoideus*, *S. malei*, and *S. cerevisiae*, from grapes apples and cereals, respectively. These yeasts are characterized by their efficient conversion of sugar to alcohol, by rapid settling after fermentation and by the production of fermented liquids of clean flavor and normal appearance.

As stated above, the desirable types of yeast are greatly outnumbered by various wild yeasts. In order that the injurious effect of these undesirable organisms may be minimized and that a desirable type of fermentation may be obtained, selected cultures of pure yeasts should be added. This addition will reverse the ratio of wild yeasts to true yeasts and will promote the type of fermentation desired. *Saccharomyces ellipsoideus*, most commonly found in grape-juice fermentations, because of its rapidity of growth and fermentation and its high alcohol-forming power, has been found most satisfactory for fermentation of fruit juices for vinegar manufacture.

For the fermentation of mashes made from starchy materials the yeasts of the *Saccharomyces cerevisiae* group are best.

Commercial Yeast Culture.—Several institutions in the United States distribute cultures of yeasts for vinegar manufacture. Addresses of these may be had from the University of California, College of Agriculture, Berkeley, Calif. The yeast is ordinarily sent to the vinegar manufacturer as a pure culture on nutrient agar-agar in a flask or tube plugged with cotton and with full directions for its increase to sufficient volume for factory use.

Using the Starter.—It will be found that 50 gal. of actively fermenting liquid will be sufficient for the inoculation of 500 gal. of fresh juice. The 50 gal. of starter is previously prepared as directed by the laboratory from which the yeast is purchased. This amount of juice should be pressed from sound, selected, and well-washed fruit, and the juice should be placed in a clean tank, preferably one that has been washed thoroughly with a sal soda solution and steamed to render it as nearly sterile as possible. It is then mixed with the 50 gal. of "starter." Within 4 or 5 days the 500 gal. of juice will be actively fermenting and can be used to inoculate about 5,000 gal. of fresh juice. The 5,000-gal. tank of juice can, in turn, be used to inoculate 50,000 gal. of juice. From this point the fermentations in the factory may be started by using 10 per cent by volume of actively fermenting juice from a tank previously inoculated by pure yeast starter.

In factories where fruit of an inferior quality is used, *i.e.*, fruit which is often fermenting or vinegar-soured when received at the factory, it will be necessary to renew the pure yeast culture frequently during the season; but if fruit of sound quality is used one culture will be sufficient for the normal vinegar-making season.

Addition of Sulfur Dioxide.—Cleaner fermentations with higher yields of alcohol are secured if from 6 to 8 oz. of potassium metabisulfite, or 3 to 4 oz. of sulfur dioxide per ton of crushed fruit, or for each 200 gal. of juice is added (see Chap. XXX for further details).

Aeration.—The growth of culture yeasts is increased by aeration and agitation of the fermenting liquid. Aeration mixes the yeast thoroughly with the fermenting liquid. It removes carbon dioxide, which has a retarding influence on fermentation, and furnishes oxygen, which favors the growth of the yeast. In the ordinary vinegar factory, however, sufficient aeration is obtained by the crushing, pressing, and pumping of the liquid before fermentation. It has been found advisable to aerate by pumping over tanks of juice that have become sluggish in fermentation and in which there is danger of "sticking," *i.e.*, complete ceasing of fermentation.

Temperature Control.—During the fermentation of any liquid in large tanks the temperature rises because of the heat liberated during the conversion of sugar into alcohol. The alcoholic fermentation of 1 gram of sugar liberates 120 cal. and the fermentation of 1 gram of sugar per 100 cc. of juice would theoretically increase the temperature 1.2°C., or approximately 2.16°F. Yeast fermentation ceases at 95 to 105°F., or approximately 35 to 40.5°C. Grape juice normally contains about 22 per cent sugar and in the fermentation of this amount of sugar the rise in temperature would be approximately 47.5°F., if no heat were lost by radiation. It has been found in commercial practice, where fermentation vats of 2,000 gal. or greater capacity are used and a normal summer temperature of 85 to 95°F. during the day prevails, that it will be necessary to cool the fermenting liquid artificially. The usual means of accomplishing cooling of fermenting fruit juices is to pump the liquid through pipes surrounded by jackets of circulating cool water. In some cases metal coils, through which cool water is circulated, are immersed in the fermenting juice.

Artificial cooling of the liquid is seldom necessary in the fermentation of apple juice, because of its low sugar content and because apples are usually crushed during the fall months when the temperature is not sufficiently high to cause "sticking" of fermentation.

High temperatures are not only injurious to yeast fermentation but also are objectionable because they favor the growth of lactic acid and vinegar bacteria. If possible, the temperature of the fermenting liquid or

pulp should be maintained between 75 and 85°F. The optimum temperature for most varieties of culture yeasts used in the fermentation of fruit juices is about 80°F.

Sanitation.—The fermentation tanks should be thoroughly cleansed before being filled with fruit juice or other liquid intended for vinegar manufacture. Not only should the tank be well washed, but it should be treated with a solution such as hot sal soda, or sulfur should be burned in the tank to destroy mold spores, vinegar bacteria, and other objectionable microorganisms. Sour press cloths, unclean crushers, pumps, etc., are prolific sources of contamination of fruit juices with undesirable types of organisms. Such equipment should be kept clean and should be thoroughly washed at the end of each day's operations.

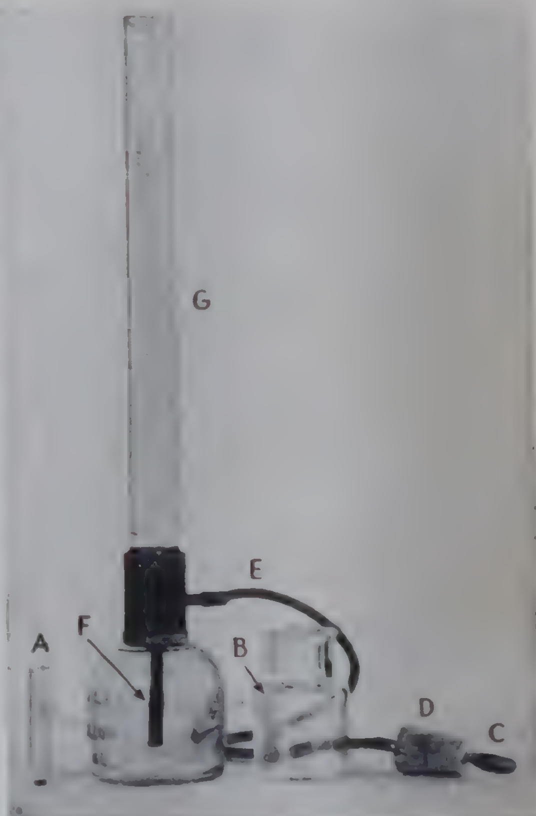

FIG. 93.—Gasometric total acidity tester for vinegar (Leo tester).

Increasing the Temperature.—The alcoholic fermentation occurs in two stages, one known as the preliminary or violent fermentation, during which most of the sugar is converted into alcohol and carbon dioxide, and fermentation is so rapid that foreign organisms find it difficult to develop. The secondary fermentation is very much slower than the preliminary fermentation and usually extends over a period of 2 or 3 weeks as compared with a period of 3 to 6 days for the preliminary period (see Fig. 93). During the secondary fermentation there is danger of contamination by vinegar bacteria, "wine flowers," and lactic acid bacteria. Should the secondary fermentation become very sluggish, it may be necessary to aerate the liquid and thus invigorate the yeast. During the cold winter or late fall months it may be necessary to heat the fermentation room artificially in order that fermentation may not be arrested by low temperatures.

Balling Readings.—The progress of fermentation is readily observed by determining the Balling of degree samples of the fermenting liquid taken daily. When fermentation is complete, the Balling hydrometer usually registers 0° or less.

Settling and Racking.—Following the secondary fermentation, the yeast and fruit pulp settle rapidly to form a compact sediment in the fermentation tank. In most factories the fermentation vats are used for

the storage of the liquid during the first 10 days or 2 weeks of fermentation only, and the final stages of fermentation are normally completed in large storage tanks often containing from 30,000 to 50,000 gal. each. In the normal fermentation the sugar content in the fruit juice or other liquid is reduced to less than 0.5 per cent sugar in a period of 3 or 4 weeks after the time of crushing. If more sugar than this is present at the end of 4 weeks, it is an indication that fermentation has been imperfect for one or more reasons. It is possible that the temperature has been too high or too low or that bacterial fermentation has retarded yeast fermentation or that the liquid contained too much sugar before fermentation. Few yeasts will completely ferment juices of more than 30° Balling.

After the fermentation is completed and the yeast has settled, the fermented liquid should be separated from the yeast sediment as completely as possible since the sediment tends to undergo decomposition, resulting in the formation of undesirable flavors or the development of lactic bacteria which seriously interfere with acetic fermentation.

The process of the separation of the liquid from the sediment is known as "racking" and is accomplished by drawing off the liquid by gravity through a faucet, by siphoning or by pumping. The residual sediment is rich in yeast and contains a large amount of liquid suitable for vinegar making which can be recovered by filtering the sediment through filter bags or filter presses, but in most factories the sediment is discarded.

Storage of the Fermented Fruit Juice.—Many vinegar factories store the fermented juices in tanks which are more or less exposed to the atmosphere. This is a mistake, for the reason that it permits the growth of Mycoderma or "wine flowers" with a resulting loss of alcohol and injury to the quality of the product. If the juice is to be held for several months, one of three things should be done. The fermented juice should be stored in well-filled closed tanks to exclude air and thereby prevent growth of Mycoderma, or if the juice is stored in open containers, it should be acidified by the addition of vinegar to increase the acidity of the liquid to at least 1 per cent acetic acid or the fermented liquid should be covered with a neutral oil which excludes air, prevents growth of "wine flowers," and reduces evaporation. Crawford states that the loss from uncovered fermented cider in 6 to 12 months may amount to 25 to 50 per cent of the alcohol. He has found the use of a mineral oil covering to be extremely effective in preventing such losses.

Alcohol Content.—The fermented liquid must not be so high in alcohol content that vinegar bacteria cannot function. Wine should be diluted to about 10 per cent alcohol content. Other fermented fruit juices usually do not require dilution.

Slow Methods of Acetification.—There are two general methods in use for the conversion of alcoholic liquids to vinegar. One of these is the slow process, of which there are several modifications, and the second method is the generator or quick process. The various modifications of the slow process and the generator process will be discussed separately.

"Let-alone" Slow Process.—In the manufacture of vinegar in the household or in the orchard, the juice is usually allowed to undergo spontaneous fermentation in barrels, and the barrels are left partially filled with the bung open until the product changes to vinegar of its own accord. The alcoholic fermentation is often incomplete and imperfect. Usually the liquid becomes covered with wine flowers and in most cases acetic acid fermentation is very slow. An abundant supply of air is necessary for the satisfactory acetification of any liquid. This fact is often not realized by the amateur vinegar maker, and it is not uncommon to observe completely filled, tightly sealed barrels or other containers set aside to become vinegar, a condition which of course prevents acetification. The "let-alone" process is very unsatisfactory, is very slow, and often results in the production of a very inferior product.

The "Orleans" process is much more desirable. In this process the fermenting liquid is placed in barrels which are filled about three-quarters full, holes are bored at both ends of the barrel a few inches above the surface of the liquid, and the bung hole in the barrel is left open. The holes should be covered with fine screen or with cheesecloth to exclude vinegar flies. To the fermenting liquid is added from one-fourth to one-fifth of its volume of fresh vinegar. This acidifies the liquid to the point where the growth of Mycoderma is prevented and the growth of vinegar bacteria promoted. It also impregnates the liquid with a very large number of active vinegar bacteria and is in the nature of a starter of vinegar bacteria. A temperature of 70 to 85°F. should be maintained. Usually at the end of 3 months the liquid will be converted into vinegar. One-fourth to one-third of the vinegar may then be drawn off for bottling purposes and an equivalent volume of alcoholic liquid added. From this point forward one-third to one-fourth of the volume may be drawn off at monthly intervals and an equivalent amount of alcoholic liquid added. This process results in aging of the vinegar during acetification and produces a vinegar superior in flavor and general quality to that of the "let-alone" process, or the generator process. It is used extensively in Europe in the preparation of vinegar from wine.

Pasteur Process.—Pasteur discovered that vinegar bacteria tended to develop on the surface of the liquid with the formation of a translucent film which he believed to be the principal agent in acetification. He also noted that in the usual Orleans process this film was disturbed during the drawing off of the vinegar and the addition of the new wine or cider

and that the tendency of the film was to settle to the bottom of the barrel, where in time the accumulation became so great that it interfered with normal acetification. The submerged film tends to destroy acetic acid. He therefore modified the Orleans process by placing on the surface of the liquid a grating made of thin strips of wood, which retained the film at the surface. By using a shallow tank and thereby increasing the ratio of the surface exposed to the volume of liquid in the tank, he obtained very rapid acetification. The liquid is acetified with one-fourth to one-fifth its volume as described above for the Orleans process.

Observations made by the writer in 1915 indicate, however, that the growth of the film is not a necessary condition. In fact, the most rapid acetification of wine and cider was obtained by the use of cultures which did not form such a film. It is possible that the growth of a heavy leathery film on the surface of the liquid tends to exclude air and actually reduce the rate of acetification.

The Generator or Quick Process.—The rate of acetification is proportional to the amount of oxygen in contact with the reacting components, or, in other words, to the surface exposed to the air, since oxygen of the air is one of the two reacting substances. If the surface, therefore, is increased, the rate of acetification is proportionately increased. This principle is made use of in the quick process, otherwise known as the "generator process" or German process.

Upright Generators.—In this method a tank, usually cylindrical and upright in form, is filled with a substance which will permit the vinegar to percolate freely and upon which vinegar bacteria may develop. The substance most commonly used is beechwood shavings, since they retain their tightly coiled condition even when wet with vinegar and therefore do not pack tightly in the generator. Corn cobs and rattan shavings are also used successfully in generators for the manufacture of fruit vinegar. The rattan shavings are tied to poles to form upright bundles, which are packed tightly in the generator. If not used in this manner, rattan shavings tend to settle into a compact inactive mass. In the manufacture of distilled vinegar, charcoal and coke have been used, although the beechwood shavings are preferred. Coke is more durable than charcoal and is sometimes used in generators in which distilled vinegar is made.

The usual generator is about 48 to 60 in. in diameter, is from 10 to 14 ft. in height, and contains three compartments. However, generators 8 to 10 ft. in diameter are also in use. A central compartment occupies most of the generator and contains the shavings or other generator material. It is equipped with adjustable openings near the bottom of the generator for admission of air. Angle-stem thermometers are inserted near the center of the compartment.

Above this compartment is a distributing compartment in which is located a tilting W-shaped trough into which the fermented liquid flows in a small stream. The axis of the trough is so placed that, when one side has filled with the liquid, it tilts and brings the other side of the trough under the stream, which in turn fills and tilts. This tilting action distributes the liquid over the bottom of this compartment which is perforated with small holes through which the liquid flows to the generating compartment below. It trickles slowly over the shavings or other filling material and is oxidized to vinegar during passage. In very large generators the liquid may be distributed by revolving perforated hard-rubber pipes acting on the principle of the familiar revolving water sprinkler used in watering lawns. The third compartment is merely a receiving chamber for the acetified liquid. By the slow process, acetification requires from 1 to 24 months, according to the temperature and other factors, and in the generator process only a few minutes, because of the enormous surface exposed for acetification. The surface of the shavings or other filling material becomes coated within a short time with a heavy growth of vinegar bacteria. The construction of such a generator is shown in Fig. 94.

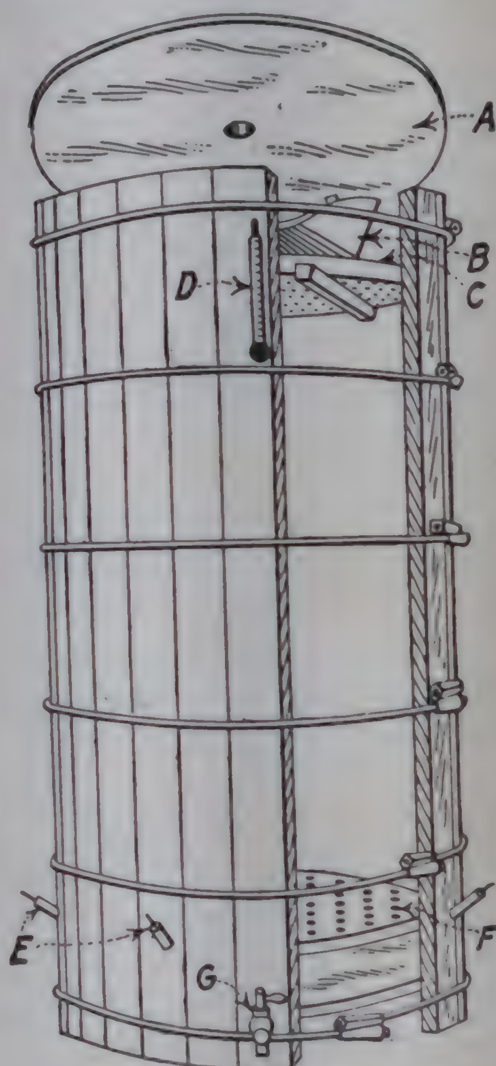

FIG. 94.—Upright vinegar generator. *A*, cover; *B*, distrbuting trough; *C*, distributing head; *D*, thermometer; *E*, air inlets; *F*, false bottom. (*Courtesy the Hydraulic Press Manufacturing Company.*)

Use of Upright Generator.—In order to start the generator, it is first necessary to acidify the shavings or other filling material, which may be done by filling the generator with new cider vinegar or other fruit vinegar. This vinegar will not only acetify the filling material but will also impregnate it with active vinegar bacteria. Following acidification of the shavings, a fermented liquid acidified with vinegar should be slowly passed through the generator in order to stimulate growth of the vinegar bacteria. Within a few days the growth of the bacteria will have proceeded sufficiently to permit normal operation of the generator.

In the usual "one-run process" the alcoholic liquid is acidified by the addition of vinegar to increase the acidity to 3 to 3½ per cent,

representing about 1 gal. of hard cider to 2 gal. of vinegar. One passage of this liquid through the generator will convert the remaining alcohol to acetic acid. In the case of cider this will mean an increase of acidity from 3 or 3½ per cent to about 6 per cent.

In the "two-run process" the freshly fermented liquid is passed through the generator to become partially acetified, and this liquid is then passed through a second generator to complete the process. There is more danger of undesirable bacterial growth and inefficient operation of the generator by the two-run process than by the one-run process, for the reason that the high acidity in the latter process checks the growth of undesirable organisms and promotes the growth of vinegar bacteria.

In California an upright generator will convert 15 to 30 gal. of alcoholic liquid into vinegar per 24 hr., *i.e.*, the conversion of a mixture of 30 to 60 gal. of vinegar and 15 to 30 gal. of alcoholic liquid to vinegar. The operation of the generator must be carefully controlled by frequent determinations of alcohol and acid of the ingoing and outgoing liquids.

Revolving Generators.—In commercial installations using this principle, a large cylinder filled with shavings revolves within a tightly constructed wooden housing. The lower half of the cylinder is immersed in the liquid to be acetified, while the upper half is exposed to the air. The exposed surface remains wet owing to rotation of the cylinder. Air is admitted to the compartment through adjustable openings. The generator revolves very slowly, at the rate of about 1½ revolutions per hour in the plant observed by the writer. The generators in question in this particular case held approximately 500 gal. each of fermented cider and approximately 3 weeks were required for complete conversion to vinegar. The revolving generator has not proved so popular as the upright type, probably because of its cost of construction and operation and its greater complexity.

Control of Temperature during Acetification.—In the slow or Orleans process the barrels of vinegar should be kept in a warm room so that the temperature in the container will be favorable for the activity of vinegar bacteria. The optimum temperature for their growth is about 85°F. In the generator process, because of the great rapidity of the oxidizing reaction, the temperature tends to rise on account of the heat liberated. One gram molecule of alcohol during its conversion to acetic acid will liberate 115 Cal. of heat, which is several times the amount of heat liberated during the fermentation of 1 gram molecule of sugar to alcohol, in which case 22 Cal. of heat are liberated. This corresponds to 2.5 Cal., or 2,500 cal. per gram of alcohol, converted to acetic acid; or enough heat is liberated by the oxidation of 1 gram of alcohol to acetic acid to raise the temperature of 100 cc. of water 25°C. (45°F.), if no heat were

lost by radiation. Usually, therefore, in the generator process the problem is one of maintaining the temperature below the danger point of 40°C. (105°F.), the temperature at which acetic acid bacteria are inactivated.

Temperature is controlled in a vinegar generator by two means: by adjustment of air intake and by rate of flow of liquid. If the temperature has become too low, it may be increased by increasing the flow of liquid and by admitting a larger volume of air through the air intakes at the bottom of the generator. This will result in the oxidation of a larger amount of alcohol per unit of time and in an increase of temperature. On the other hand, if the temperature rises above the optimum of 85°F., the rate of flow of the liquid must be decreased and the air intake reduced. During the warm summer months the temperature of the generators must be carefully regulated to prevent excessively high temperatures. The output of generators during the winter months will be greater than during the summer months for the reason stated above, other things being equal.

Losses during Acetification.—In the operation of generators appreciable amounts of alcohol and acetic acid are lost by evaporation, by oxidation to carbon dioxide and water, and by being utilized by the vinegar bacteria for their growth. Small amounts of alcohol also remain unconverted in the finished product. Theoretically 1 gram of alcohol should yield 1.304 grams of acetic acid. In practice 1 cc. (0.7938 gram) of alcohol normally yields about 1 gram of acetic acid, instead of the theoretical 1.035 grams, and 1 gram of alcohol yields only 1.26 grams of acetic acid. In improperly regulated generators, where the supply of air passing through the generator is too great, the yield may be much less than this. In extreme cases it is possible for all of the alcohol entering the generator to be converted into carbon dioxide and water with the formation of practically no acetic acid. The reaction involved in this case is $C_2H_5OH + 3O_2 = 2CO_2 + 3H_2O$. It is very essential, therefore, that the proper balance between air intake and flow of alcoholic liquid be maintained.

Aging of Vinegar.—Freshly made vinegar, especially that prepared by the generator process, is very harsh in flavor and odor. It has been claimed that this flavor is due to the presence of higher alcohols, acetaldehyde, and acids. If new vinegar is placed in well-filled tanks or barrels and allowed to stand for 6 months or a year, the harsh flavor disappears and is replaced by a mild agreeable flavor and pleasing "bouquet" or odor. The changes that occur during this period are probably similar to those that occur in the aging of wine. The combination of ethyl alcohol and acetic acid, according to the following reaction, to form ethyl acetate, is an example of the reactions that probably occur during aging.

$$C_2H_5OH + CH_3CO_2H = CH_3CO_2C_2H_5 + H_2O$$
$$\text{ethyl alcohol} + \text{acetic acid} = \text{ethyl acetate} + \text{water}$$

In the slow process of vinegar manufacture, aging and acetification occur simultaneously and therefore such vinegar is ready for use when acetification is complete. Vinegars from generators, on the other hand, should not be used until they have been aged for at least 6 months. Aging should take place in well-filled wooden containers, as it has been found that it does not occur satisfactorily in glass. The reason offered for the superiority of wood over glass is that wood permits the slow oxidation of the vinegar by the air which enters through the pores of the wood. Aging takes place more rapidly and satisfactorily in small cooperage than in very large tanks.

Fining of Vinegar.—Vinegar to be attractive should be brilliantly clear, which condition may be accomplished by either filtration or fining.

Common fining materials are "isinglass," casein, gelatin, Spanish Clay, and high-grade bentonite clay. The unground dry clay is soaked several days in water and is then broken up into a fine suspension by vigorous agitation to give a "solution" containing 5 per cent of the clay. This can be done easily by arranging a barrel on a shaft so that it may be rotated. Water and powdered clay may be rapidly converted to a smooth "solution" by mechanical stirring in an open barrel. To clarify the vinegar about 1½ gal. of the 5 per cent suspension is mixed thoroughly with each 100 gal. of vinegar, and the mixture is allowed to settle. After settling the clear liquid is racked.

It is desirable to make a preliminary clarifying test with small bottles of vinegar with a standard 5 per cent suspension of the clay in order to determine the amount necessary for the larger amount of vinegar.

"Isinglass," fish glue dissolved by soaking in water acidified with citric acid equal in weight to the amount of isinglass used, is also a good clarifying agent. An ounce of isinglass may be dissolved in ½ gal. of water by soaking for 24 hr. in the acidified water and by rubbing the soaked isinglass through a fine screen. To clarify the vinegar the solution is added to 50-gal. barrels and thoroughly mixed by stirring. The barrels are closed, the liquid allowed to settle for a week or 10 days and the clarified vinegar separated from the sediment by siphoning.

Casein is also an excellent clarifying agent. A 2 per cent solution in ½ per cent sodium bicarbonate is prepared by heating. The usual dosage is 1 gal. of this solution per 100 gal. of vinegar.

Vinegar may also be clarified with tannin and gelatin as described for wine. The tannin is dissolved first in the vinegar and mixed thoroughly with it. The gelatin is dissolved in water by heating approximately 4 oz. of gelatin in each gallon of water. Approximately equal proportions of

the tannin and gelatin are used. The usual dosage is 2 to 4 oz. of each per 100 gal.

Filtration.—The usual method of clearing vinegar is that of filtration. A very satisfactory filter is a filter press consisting of plates and frames of corrosion-resistant aluminum bronze. A small amount of infusorial-earth filter aid, such as Hy-Flo Super Cel or Dicalite, is added to the vinegar before passing it through the filter press. The filter aid builds up a filtering layer on the cloths of the filter press.

The pulp filter such as described in Chap. XV also may be used. However, it should be constructed of stainless steel or other resistant metal and not of copper or tinned copper, as these metals are corroded by the vinegar and may then cause clouding.

For polishing filtration of vinegar for bottling, any good type of pad filter such as the Ertel, Seitz, Lomax, and others may be used. The vinegar must be previously roughly filtered or fined, as a polishing filter of this type will soon become clogged and cease to operate if used with cloudy vinegar.

Metal Haze.—White wine vinegar is subject to clouding if it contains an excess of iron dissolved by the juice or vinegar from equipment such as pumps, pipe lines, etc. In other words, iron casse is likely to develop when ferrous iron from such sources oxidizes to the ferric condition. The ferric ions react with tannin, phosphates, and probably with proteins to form colloidal precipitates that make the vinegar hazy or cloudy.

Clarification with casein accompanied by addition of bentonite, Spanish Clay, or other clarifying clay will usually stabilize the vinegar against subsequent iron clouding (see also discussion of iron casse in Chap. XXX).

Tin and copper salts also may cause clouding. Pumps, pipe lines, filters, and other equipment which come in contact with the must or vinegar should be of resistant metal, preferably stainless steel, or of hard rubber or wood. Resistant bronzes are now commonly used for construction of pumps and filters, while hard rubber is generally used for vinegar pipe lines and even for pumps.

Pasteurizing Vinegar.—After filtration, vinegar sometimes becomes cloudy because of the growth of vinegar bacteria. This may be prevented by heating the filtered or clarified vinegar to 140°F. for a few seconds. The pasteurization of vinegar in bulk is accomplished by heating it in a continuous stream in a steam-jacketed block tin or aluminum pipe to the pasteurizing temperature and cooling it at once in a water-cooled coil. Bottled vinegar may be pasteurized by immersing the filled bottles in tanks of water and heating the contents of the bottles to 140°F., as described in Chap. XV; or by flash pasteurization accompanied by filling the bottles hot at 150 to 160°F. Close filtration into sterile bottles may also be used as a means of preservation.

Containers for Vinegar.—Vinegar is marketed in barrels and in bottles. Formerly oak barrels were commonly used for bulk vinegar, but at the present time spruce is used extensively, the interior of the barrels being heavily coated with paraffin. Barrels for shipment of bulk vinegar should, of course, be thoroughly cleansed before use and should be free of any moldy or other disagreeable flavor or odor.

The best grades of vinegar are most profitably marketed in glass containers. Vinegar in bottles should be brilliantly clear, well aged, and of pleasing flavor and odor. The bottles are, at the present time, sealed with the ordinary crown cap of the type described elsewhere for fruit juices. The inner cork seal of such caps must be of the best material so that the acetic acid may not penetrate to the metal. Bottled vinegar should be pasteurized in order that it may not become cloudy through the growth of vinegar bacteria.

Vinegar Eels.—One of the most common diseases of vinegar is that caused by the growth of the vinegar eel *Anguillula aceti*. This organism is about 1/16 in. in length and is very slender. It can be seen in vinegar contaminated with it by holding a small sample to the light in a tumbler or test tube, but it is more readily observed with a hand lens. It often occurs in vinegar generators, but may also be present in the alcoholic liquid before acetification takes place. It is believed that it is distributed by spoiled fruit and by vinegar flies. Generators may become so badly contaminated with the eels that acetification is interfered with. In such cases it becomes necessary to remove the filling of the generator, to sterilize it with live steam and to sterilize the shavings or other generator material with steam or boiling water. Hard cider or other liquid contaminated with the eel should be pasteurized and filtered. Tests indicate that the eel can be destroyed by a temperature of 130°F. The organism is strongly aerobic and therefore does not develop rapidly in bottled vinegar.

Slimy Generators.—Vinegar generators sometimes become slimy, which condition is usually caused by operating the generator too long without cleaning the filling material. Organisms may develop under these conditions which convert the alcohol in the liquid to carbon dioxide and water and thereby greatly reduce the strength of the vinegar. The cure and prevention consist in thoroughly cleansing the generator and its contents occasionally and in operating the generator carefully, maintaining the proper balance between air supply and flow of liquid. It is usually necessary to clean the shavings near the top of the generator frequently.

Wine Flowers.—"Wine flowers," as noted elsewhere, may become a serious disease of fermented fruit juice and are very prevalent in cider vinegar factories. Storage of the fermented juice in well-filled sealed

containers or the acidification of the fermented liquid by the addition of vinegar are the two most effective means of controlling the growth of wine flowers (Mycoderma). Air can be most effectively excluded from the stored fermented cider by a covering of neutral mineral oil.

Lactic Bacteria.—In the small-scale manufacture of vinegar from fruit juices the fermented liquids will often be found to be teeming with lactic acid bacteria, commonly rod-shaped, nonmotile, and about 6 to 10μ in length and about $\frac{1}{2}\mu$ in width. These organisms often produce a disagreeable mousy flavor and odor, cause cloudiness, and interfere with acetification. The bacteria are facultatively anaerobic and develop very frequently in symbiosis with *Mycoderma vini*. Their growth is reduced by the use of pure cultures of yeast and is favored by the presence of residual sugar in the fermented liquid. Filtration and pasteurization of the fermented alcoholic liquid may be used to eliminate this organism in cases where it has become a serious disease. A very effective preventive measure is the addition of sufficient vinegar to increase the acetic acid content to about 1 per cent. Seventy five parts per million of sulfur dioxide also prevents its growth (see Fig. 3 for appearance of Tourne bacteria).

Vinegar Flies.—The vinegar fly, *Drosophila cellaris*, a very small fly which propagates in piles of fermenting pomace or in rotten fruit or in crevices around the generators, is an almost universal pest in vinegar factories. Its numbers can be reduced by strict observance of sanitary conditions in and around the plant and by disposal of the pomace in such a manner that the flies cannot find a suitable breeding place. Screening of the outlets and tops of the generators and of the doors of the generator room will make conditions in the generator room unfavorable to its existence. The fly does not affect the quality of the vinegar but is an obnoxious pest to the workmen and probably carries vinegar eels from tank to tank in the storage room.

Vinegar Louse.—This is a very small form of aphid which develops in and around generators under certain conditions. It rarely, however, becomes a serious pest.

Analysis of Vinegar and Fermented Juices.—Determination of acidity, alcohol, and extract is essential in the modern vinegar plant. The manufacturer should know the acid and alcohol content of the liquid entering the generators and of the vinegar issuing from them in order that improper functioning of the generators may be quickly detected. Pure food law standards must be met and the manufacturer must be certain that his product conforms in composition to such regulations. Methods of determining the more important constituents are given in Cruess and Christie's "Laboratory Manual of Fruit and Vegetable Products" and in "Official

and Tentative Methods of Analysis," Association of Official Agricultural Chemists. The acid tester shown in Fig. 93 is useful in plants that do not employ a chemist.

Application of Results of Vinegar Analysis.—To be of greatest value to the vinegar manufacturer the results of analysis must be properly interpreted.

Total Acid.—The Federal Pure Food and Drug Act requires that vinegar contain at least 4 per cent acetic acid. Most state pure food laws are identical with the federal law in this respect.

In distilled vinegar total acid and volatile acid are practically identical, but in fruit vinegars an appreciable proportion of the total acidity represents fixed organic acids, such as malic, citric, and tartaric acids. For a given fruit vinegar, however, the fixed acidity is a fairly constant quantity, and if this correction factor is applied, the volatile acidity can be determined with reasonable accuracy from the total acidity. In most cases a vinegar is considered to fulfill the legal requirement in regard to acidity if it contains 4 per cent total acids calculated as acetic acid. Four per cent total acids as acetic is equivalent to "40 grains" by the Leo acid tester. Most producers do not market vinegar of less than 4.5 per cent total acid as acetic.

Generators are sensitive to changes in the composition of the "wash" entering them, and after the proper proportions of vinegar and alcoholic liquid for the "wash" have been determined, this ratio should be maintained constant. Total acid determinations of the two components and of the blend or "wash" are therefore essential.

Alcohol.—Balling tests of the unfermented juice and alcohol determinations upon the fermented juice are necessary in determining the efficiency of yeast fermentation.

Alcohol determinations must be made upon the "wash" entering the generators and of the vinegar emerging from them in order to insure that the conversion of alcohol to acetic acid is efficient and that the vinegar does not contain too large an amount of unconverted alcohol. Generator vinegar should contain less than 0.5 per cent of alcohol and 1 per cent of alcohol by volume should yield at least 1 per cent of acetic acid.

Sugar.—A good vinegar should contain less than 0.3 per cent of sugars. A higher percentage indicates incomplete fermentation, usually caused by the presence of an excessive amount of acetic acid during yeast fermentation.

Blending.—The results of analyses are very valuable in the blending of vinegar to maintain a product of uniform composition. Blending is usually necessary because of the variation in composition of the raw material and of the variation in acetification. In most cases total acid forms the principal basis for blending.

Various blending formulas may be employed but the following formula is simple and easily applied.

Let c = per cent acid desired.
a = per cent acid in vinegar of higher acidity.
b = per cent acid in vinegar of lower acidity.
a' = gallons of vinegar a in blend.
b' = gallons of vinegar b in blend.

Then:

$$c - b = a'$$
$$a - c = b'$$

Example:

$$a = 6 \text{ per cent total acid}$$
$$b = 3 \text{ per cent total acid}$$

required proportion of each to give a blend, $c = 4$ per cent.

$$4 - 3 = 1 \text{ gal. of vinegar } a \text{ (6 per cent)}$$
$$6 - 4 = 2 \text{ gal. of vinegar } b \text{ (3 per cent)}$$

This formula may be applied also to the diluting of vinegar with water but in this case b becomes 0.

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CHAPTER XXV

PICKLES

The manufacture of pickles, relishes, and condiments is one of the most important of the food industries. Although the preservation of vegetables and fruits in pickled form began as a household art, at present most of the world's supply of pickles is produced in commercial plants.

Types of Pickle.—The cucumber, one of the most important raw materials used for pickles, is packed in many forms: *e.g.*, in plain or spiced sweet vinegar in jars, kegs, or cans fermented in spiced brine as dill pickles; packed in mustard; or in chopped form in various relishes. Green tomatoes, peppers, cauliflower, and onions are common ingredients of mixed pickles, chowchow, etc.

Sauerkraut is an extremely important pickled product. Advertising of the healthfulness of its juice has increased the demand for "kraut."

The olive is the most important fruit used in pickled form. The pickling of ripe olives is described in Chap. XII. Various fruits, but more particularly peaches, figs, and pears, are used in important quantities for sweet spiced pickles. In European countries pickled walnuts are popular.

CUCUMBER PICKLES

The cucumber, according to Le Fevre, is one of the oldest of the garden vegetables, originating in the Far East at least 3,000 years ago. Although of semitropical origin, it can be grown successfully in practically any locality, provided care is taken to avoid exposure to frost.

The processes of preparing and pickling cucumbers apply in some respects to other vegetables, and for this reason cucumber pickling will be presented first.

Varieties.—Cucumbers for pickling purposes should be of varieties that are firm, of regular form, and of good keeping quality. Very large cucumbers are not so desirable for pickling as the smaller sizes.

Le Fevre recommends the Chicago Pickling, Boston Pickling, and Snow's Perfection as among the best varieties for pickling.

Harvesting.—In harvesting cucumbers for pickling, great care should be taken to avoid bruising, and it is customary to leave $\frac{1}{4}$ to $\frac{1}{8}$ in. of the stem attached.

Cucumbers for pickling should be slightly underripe rather than fully mature.

The cucumbers deteriorate rapidly after picking and should be delivered to the factory or salting station as promptly as possible. The time between harvesting to brining should not exceed 6 to 8 hr. Sorting to remove "nubbin" and "crook" cucumbers and to roughly grade the cucumbers for size is frequently done before salting. The larger cucumbers sorted out at this time may be barreled for preparation of dill pickles.

Salting and Fermentation.—Cucumbers must undergo a preliminary fermentation in brine before they are placed in vinegar. A number of different types of bacteria and yeasts are present during fermentation, but the predominant and desirable organisms are lactic acid bacteria.

The fermentation and salt curing of the cucumbers are conducted in circular wooden vats from 8 to 14 ft. in diameter and 6 to 8 ft. in depth and so placed as to extend about 3 ft. above the floor of the vat room.

Brine of 40° salometer to a depth of about 1 ft. is placed in the bottom of the vat to prevent bruising of the cucumbers as the vat is filled. After the vat is filled, brine is added to cover the cucumbers. Some packers add salt at this time, relying on osmosis to form brine; but filling the vat with 40° salometer brine is considered to give better results. A circular wooden head is then placed in the vat over the cucumbers and is held in place by 4- by 4-in. crosspieces secured at the ends of iron clamps. The cover is necessary to keep the cucumbers submerged in the brine, particularly during fermentation.

The concentration of the brine placed on the cucumbers is generally "40° salometer," *i.e.*, approximately 10 per cent salt. Since cucumbers contain more than 90 per cent water, the brine rapidly decreases in concentration during fermentation and storage. A minimum concentration of 10 per cent salt (40° salometer) should be maintained during fermentation, to prevent the growth of putrefactive organisms. On the other hand, if the concentration greatly exceeds 10 per cent salt, the activity of the lactic acid organisms is greatly retarded. During the first week of fermentation it is customary to add salt to the vat each day, draw off the brine from the bottom of the vat and pump it over the top until the brine is of uniform concentration throughout the vat.

Le Fevre has found that the addition of about 1 per cent of sugar (preferably dextrose) to the brine greatly improves the character of the fermentation because some cucumbers are deficient in sugar and are liable to develop undesirable types of bacteria unless a small amount of sugar is added to the brine.

The fermentation and curing process normally requires from 4 to 6 weeks, during which period the brine is maintained at about 10 per cent salt (40° salometer) by adding salt to the top of the tank and occasionally

pumping over in order to make the concentration uniform. Too frequent pumping over is considered undesirable, however, as it may stimulate the growth of aerobic spoilage organisms. When fermentation is complete, the salt concentration of the brine is gradually increased and maintained at about 15 per cent salt (60° salometer).

During fermentation and curing, the cucumbers change in color from a bright-green to an olive-green or yellowish-green color, and the flesh of a completely cured cucumber becomes translucent and no longer chalky-white and opaque.

The cucumbers carry considerable numbers of yeasts, bacteria, and molds. Consequently, the brine is well inoculated naturally. During the early stages of fermentation, gas-producing organisms predominate. Subsequently gas formation nearly ceases, but lactic fermentation continues. Normally the brine attains about 0.6 to 0.8 per cent total acidity expressed as lactic, although considerably higher acidity is sometimes reached. Some alcohol is formed by yeasts. Bacteria form small amounts of acetic and propionic acids.

The lactic acid bacteria occurring in pickle brines, when observed microscopically, are usually found to be long rods, frequently occurring in pairs. They resemble the so-called Tourne bacteria that cause spoiling of cider vinegar stock and wine. The lactic bacteria are facultative anaerobes, growing better in the absence of air. They are more resistant to salt than are bacteria of the colon group, hence if the brine concentration is maintained at 40° salometer during fermentation, there is little danger of spoilage from these organisms.

A convenient device for preparing brine consists of an open 50-gal. barrel on a small hand truck. Salt is placed in the bottom of the barrel; a stream of water from a hose enters near the bottom, stirring the salt continuously. A hose or pipe connected near the top of the barrel conducts the brine to the vat. Operation is continuous. So-called "half ground rock salt" is generally used.

In filling the vat the cucumbers and salt should be weighed and the water metered in order that the resulting brine may be of the desired concentration. One pound of salt per gallon makes a brine of approximately 41° salometer.

At one time dry salting was generally used. Dry salt was added and water was extracted by osmosis from the cucumbers to form a brine. The objection to this method is that it may cause collapse of the cucumbers to such extent that they do not regain their original size and form during processing after removal from the brine.

During fermentation the cucumbers become very permeable and consequently absorb salt rapidly to come to equilibrium with the surrounding brine.

Fabian, Bryan, Etchells, and Nienhuis of the Michigan Agriculture Experiment Station studied several factors important in the fermentation of cucumbers. They decided that the addition of sugar to the brine is highly desirable in order to secure optimum acidity. The sugar is added after most of the natural sugar of the cucumbers has been fermented. Peptonizing bacteria predominate in the initial stages of fermentation but practically disappear subsequently, being replaced by acid producers. Fermentation was more rapid at 30° salometer than at 40° salometer brine, but it is more difficult to control fermentation at the lower salt concentration. The addition of a small amount of acetic acid to 30° salometer brine was beneficial but unduly retarded fermentation at 40° salometer. Some of their other conclusions are given in the paragraph on softening.

Storage.—After fermentation is complete the salt content of the brine is increased to 60 to 66° salometer. If properly cared for, the cucumbers may be held in this brine almost indefinitely.

If the vats are indoors, a heavy, wrinkled, white film, becoming gray with age, develops on the surface of the brine. The film is made up chiefly of yeast-like organisms. E. M. Mrak of this laboratory finds them to belong to the genus Debaromyces, genus Mycoderma, and genus Pichia for the most part, although the film is commonly termed Mycoderma. Some of these yeasts are very tolerant to salt concentration, Joslyn and the writer having encountered several that grew at 20 per cent salt, nearly 80° salometer. They destroy lactic acid by oxidation and, if undisturbed, will eventually reduce the acidity so greatly that spoilage organisms will develop. Joslyn found that the acidity of 100-cc. portions of pickle brine stored at room temperature in 4-oz. bottles was reduced from 1.13 grams per 100 cc. to 0.25 gram in 26 days. In storage vats the rate is very much less owing to the great depth of the liquid, nevertheless it is appreciable.

In most factories the "scum" yeast is regularly removed by skimming in order to minimize its undesirable effect. A much more effective preventive measure consists in floating a layer of neutral mineral oil (confectioners' slab oil) about ⅛ in. thick on the surface. The objection to this measure is the danger of coating some of the cucumbers with the oil when the vat is emptied. However, most of the oil may be skimmed from the surface and the remainder floated off by adding water to fill the tank to overflowing. Vats stored in open sunlight do not develop "Mycoderma" film as the sunlight prevents its growth. Ultraviolet has been used successfully indoors as a preventive, but the installation appears to be too costly to be practicable.

Joslyn and Cruess (1929) conducted an extensive investigation of 16 strains of film yeasts from pickle brines, particularly in respect to their

oxidative properties and salt tolerance. One grew at 20 per cent salt, 75.5° salometer, in cucumber brine of pH 5.1, four grew at 19 per cent salt but not at 21 per cent, and seven were inhibited by 14 per cent or less salt. At lower pH values less salt was required to prevent growth. At 65° salometer only 0.4 per cent acetic acid was required to prevent growth of all strains, and at 44° salometer 1.0 per cent was required. The sensitiveness of these yeasts to acetic acid provides an inexpensive method of preventing their growth. At 65° salometer 0.01 per cent sodium benzoate was required to prevent their growth and at 44° salometer, 0.06 per cent. The yeasts were able to use most sugars and many organic acids as sources of carbon. Most of the yeasts were destroyed at 60°C. in 10 min., although 30 min. at 60° was required for one and 30 min. at 65°C. for another. All were very sensitive to sunlight and failed to grow when exposed to it continuously.

Per Cent Salt and Salometer Degree.—Brines are usually tested by a hydrometer known as a "salometer" or "salinometer." Salometer degree is approximately equal to per cent salt multiplied by 4, as shown in Table 78, compiled by Le Fevre. Baumé degree is also frequently used. It is approximately equal to per cent salt.

TABLE 78.—PER CENT SALT AND SALOMETER DEGREE OF BRINES
(After Le Fevre)

Per cent salt in brine	Salometer degree	Per cent salt in brine	Salometer degree
1.06	4	7.42	28
2.12	8	8.48	32
3.18	12	9.54	36
4.24	16	10.60	40
5.30	20	15.90	60
6.36	24	21.20	80
		26.50	100

Softening.—Softening of cucumbers during fermentation or storage, which sometimes occurs, is usually an indication of use of a too weak brine. Le Fevre has found that the concentration of the brine should not fall below 8 per cent salt, in order to inhibit the growth of *Bacillus vulgatus*, the organism found in his investigations to be chiefly responsible for softening. "Slippery" pickles are those in the first stages of softening. The condition is apparently due to decomposition of pectic substances of the middle lamella. Lesley and Cruess believed from their work that the softening of dill pickles may be due to high acidity. Joslyn suggests that certain bacteria developing during the initial fermentation secrete pectolytic enzymes that later cause softening by hydrolysis of protopectin,

a theory later confirmed by Fabian and associates. Young, immature cucumbers are more susceptible than others. Softening begins at the blossom end. Cucumbers badly affected by mosaic disease are very apt to soften during fermentation. Acidification of the fresh brine was found by Lesley and Cruess to inhibit subsequent softening; evidently by preventing growth of pectolytic bacteria.

Fabian and associates found that ropy (slimy) brine is caused by development of encapsulated bacteria during fermentation of brines of too low salt and acid content. They recommend rapid building up of the salt content as the best means of preventing this condition.

Blackening of the brine sometimes occurs. Fabian and associates find that it is in some cases due to formation of iron sulfide. The hydrogen sulfide comes from the decomposition of protein and the necessary iron salts from the water or equipment, such as cast-iron pumps, iron pipes, etc. In other cases the black color is a soluble pigment formed by *Bacillus nigrificans* n. sp.; the necessary conditions being the presence of a sugar, as dextrose, low nitrogen content, and a neutral or slightly alkaline reaction.

If the mycoderma film is allowed to develop undisturbed, it will eventually destroy the lactic acid of the brine and induce softening and destruction of the cucumbers by spoilage organisms.

Sorting and Grading.—The cured cucumbers are known as "salt stock." They are very salty to the taste, are firm in texture, and possess a pleasing fermented flavor. Before being placed in vinegar, they must be sorted, graded for size, and processed.

Sorting is done by women as the cucumbers pass before them on a broad belt.

The size grading is generally done by a revolving cylinder with holes of various sizes or by vibrating screens made of parallel strips of metal or hardwood. Some picklers grade the cucumbers for size by hand, claiming that mechanical graders do not give very uniform size grades on account of the irregular shape of the cucumbers.

Size Grades.—The size grades and size designations vary somewhat in different plants, although certain terms such as Gherkins, Midgets, etc., are in common use. Cucumbers 1¼ to 2 in. long are usually termed Midgets. These may be divided into three further size grades, designated Number One, Number Two, and Number Three Midgets, averaging about 650, 450, and 340 per gallon, respectively. Gherkins are usually 2 to 2¾ in. long and may be classes as Number One, Two, and Three Gherkins, averaging approximately 260, 225, and 160 per gallon, respectively. Cucumbers for sweet pickles and for fancy keg stock are 2¾ to 3½ in. long. According to Le Fevre the Medium grade cucumbers are 3 to 4 in. long, and according to Shinkle 3½ to 4 in. long. The Large size

is 4 in. or more in length. Le Fevre gives the Medium grade as 40 to 120 per gallon and Large as 12 to 40 per gallon.

The pickler generally speaks of size grades for cucumbers in terms of the number per 45-gal. keg, *e.g.*, Midgets, approximately 15,000 to 30,000, Gherkins, approximately 7,500 to 12,000, Medium, approximately 3,600 to 1,800, and Large, 1,000 or less per 45-gal. keg.

Very large pickles are generally sliced or chopped and used for mixed pickles, relishes, etc.

The National Picklers' Association has adopted quality standards for cucumber pickles and salt stock.

Processing.—The salt must be removed from the salt stock (cucumbers from brine) by soaking in water before placing in vinegar. One method consists in covering the cucumbers with hot water and bringing the mixture to 110 to 130°F., the temperature depending on the texture and size of the cucumbers. They are allowed to stand about 10 to 14 hr. with occasional stirring. Fresh water is then applied, and they are allowed to stand several hours at about 110 to 130°F. Usually a third soaking is necessary. It is customary to add about 1 lb. of soda alum to each 25 gal. of the third wash water to harden the cucumbers and about 2 oz. of turmeric to improve the color. The use of these substances must be declared on the label. Calcium chloride also has a hardening effect, from 0.3 to 0.5 per cent in the final wash water being sufficient.

The salt may be removed also by 1 to 2 days' soaking in cold water which is changed two or three times daily, followed by 10 to 12 hr. at 110 to 130°F. in hot water. If the cucumbers are very tough, it may be necessary to elevate the temperature to 140 to 150°F. a short time; normally, however, 110 to 130°F. is sufficient.

Most other vegetables after curing in brine are soaked in several changes of cold water until practically free of salt. Alum is usually added as for cucumber pickles. Warm water is used for soaking the salt out of onions. Cauliflower must be handled carefully and not heated to a very high temperature so that breaking of the curds will not occur.

Sour Pickles.—Distilled vinegar is used almost to the exclusion of other vinegars for pickles, because of its uniform composition, neutral flavor, light color, and low cost.

The cucumbers are often first placed for a few days in a weak vinegar, *e.g.*, "40 to 50 grains" strength (4 to 5 per cent acidity as acetic). This is then removed and replaced with the final vinegar of 30 to 50 grains strength. A vinegar of "40 grain" acidity (4 per cent acetic acid) is generally sufficiently sour. If the vinegar is too low in acid, the pickles are apt to spoil. The final acidity should be 2.5 per cent or higher.

In one California factory the cucumbers are placed in a 55- to 65-grain (5.5 to 6.5 per cent acetic acid) distilled vinegar directly after processing

and sorting. The water and juice of the cucumbers dilute the acidity of the vinegar, and the pickles absorb the vinegar. At equilibrium the average acidity of the pickles and the vinegar is 20 to 35 grains (2 to 3.5 per cent acetic acid).

Fancy bottle or small keg-pack pickles usually receive a weaker vinegar than bulk pickles in barrels.

Sweet Cucumber Pickles.—The cucumbers are prepared as for sour pickles, but in order to prevent shriveling by the osmotic action of the sweet vinegar, the processed cucumbers are first stored in plain vinegar of about 5.5 per cent acidity for a few days and are then placed in a spiced, sweet vinegar.

Many formulas for the preparation of the spiced, sweet vinegar are in use. One consists of 8 gal. of distilled vinegar of 8 per cent acetic acid, 20 lb. of sugar (10 lb. brown sugar and 10 lb. refined white sugar), and 1 oz. each of whole cloves, coriander, mustard seed, broken ginger root, and mace. The spices are heated in a bag in the vinegar before addition of sugar to 175 to 200°F. for about 1 hr. in a covered vessel. Any loss in volume is replaced by adding water after extraction of the spices. The spices are removed and discarded, and the sugar is dissolved in the hot spiced liquid. The vinegar should test approximately 40° Balling at 60°F. and contain 5 per cent total acid calculated as acetic acid.

Some manufacturers add sufficient sugar to 55- to 60-grain vinegar to give a sweet liquor of approximately 40° Balling. The cucumbers are stored in this vinegar for several weeks. It is then replaced with a fresh spiced vinegar made to 55° Balling with added sugar. A 100-grain (10 per cent acetic acid) vinegar made to 55° Balling with sugar will drop to about 4 to 4.3 per cent owing to dilution with the sugar.

In some cases it is necessary to proceed more slowly in order to prevent shriveling. In other words, the cucumbers are stored in a spiced vinegar syrup of which the sugar content is progressively increased by sugar additions of intervals of several days. This procedure permits the cucumbers to absorb the sugar gradually.

A few parts per million of copper is apt to impart an undesired green color to the cucumbers. Consequently it is well to avoid contact of the vinegar with copper or brass equipment.

Usually cucumbers are mixed with other vegetables in the preparation of sweet pickles; onions, green tomatoes, and cauliflower generally being used for this purpose. Frequently whole spices also are mixed with the pickles in the final package.

Dill Pickles.—Dill pickles are prepared by fermentation in a dilute brine flavored with dill herb and spices and are marketed in this brine rather than in vinegar. A weaker brine is used than for the fermentation of cucumbers for vinegar pickles because it permits rapid fermentation.

During fermentation, 50-gal. barrels are used as containers for the cucumbers. In filling the barrel, the head is removed and a layer of dill herb 2 to 3 in. in depth is placed in the bottom of the barrel; cucumbers are then added to fill the barrel about one-half full and mixed dill spices are added. A layer of dill herb is placed on the cucumbers, and the barrel is filled to within 2 or 3 in. of the top. Often the dill weed is preserved in season by storing in 100-grain vinegar or in very strong brine. The vinegar pack is preferred as the flavor is retained more satisfactorily. The dry plant is also sometimes used. Dill spices are added, and a layer of dill herb placed on the cucumbers. A total of 6 to 8 lb. of green, vinegar packed, or salted dill herb or 1½ to 3 lb. of the dry plant is used. If the brined herb is used, the brine should also be added to the cucumbers.

A total of about 1 qt. of mixed dill spices is used per 50-gal. barrel of pickles. This mixture consists of approximately equal weights of whole cloves, coriander, and black pepper and about 1 lb. of dry bay leaves per 15 lb. of the mixed whole spices.

The filled barrel is headed up, and the hoops are driven to make the barrel watertight; through a hole in the head of the barrel, a 40° brine (10 per cent salt) is added to fill the barrel to overflowing. The brine should be acidified with about 1 qt. of 100-grain vinegar per 10 gal. of brine in order to stimulate the growth of desirable organisms. The barrel is stored in a warm room and fermentation allowed to proceed. A temperature of about 80°F. is best since at lower temperatures fermentation is slow and at higher temperatures spoilage or the formation of hollow pickles may occur. The bunghole is closed during violent fermentation except for a small hole through the bung to permit escape of gas. As fermentation proceeds some liquid is lost by frothing, and fresh 24° brine must be added to keep the barrel well filled. It is then tightly sealed.

The pickles should be ready for use within 6 weeks after beginning of the fermentation.

Dill pickles attain about 1½ per cent of total acid expressed as lactic acid. The barrels must be kept well filled and sealed after curing is complete, otherwise film yeasts will destroy the acidity and spoilage bacteria will then develop.

Dill pickles also frequently exhibit softening or slipperiness at the blossom end, although they are normal in all other respects. Lesley and the author concluded that this deterioration might in some cases be due to use of immature cucumbers plus hydrolysis of pectic substances by high acidity. Others, including Joslyn and Fabian, have believed that it may in many cases be caused by enzymes elaborated by spoilage bacteria shortly after filling of the barrels, for at that time the acidity is sufficiently low to permit the growth of such organisms. Acidification of the initial brine, as previously described, greatly reduces loss, tending to confirm

this theory. Fabian has proved recently the validity of the theory. Probably natural pectin splitting enzymes of the cucumbers also are involved in this phenomenon. It is recognized that use of immature cucumbers predisposes the product to this form of deterioration.

Dill pickles should be consumed within a few months after curing is complete, as they do not keep so well as vinegar pickles. If they are to be held for a relatively long period, the salt concentration of the brine should be increased to about 30° salometer. They are also preserved by canning in the manner described in the following paragraph.

So-called process dill pickles are made by soaking salt stock cucumbers in hot water to remove salt followed by storage in barrels with dill plant, dill spices and brine acidified with vinegar. They are inferior to the "true" dill pickles previously described.

Canning and Bottling.—Cucumber pickles of all kinds and mixed pickles are now successfully canned in heavily lacquered cans.

In one California factory the cucumbers are packed into the cans carefully by hand; brine, vinegar, or spiced sweet vinegar, as the case may require, is added. The cans are given a very thorough exhaust at 200°F. (about 8 to 10 min.), they are sealed, and no further sterilization is given. Exhausting removes air, expands the contents, and thus creates a vacuum in the can. Good results are also obtained if, after exhausting and sealing, the sealed cans are processed for about 10 min. in water at 185 to 200°F.

Pickles packed in glass are usually not sterilized. The pickles are packed into the jars by hand, according to a definite pattern. The packed jars are filled with vinegar or sweet spiced vinegar and sealed, usually in vacuum. No heating is required for glass-packed pickles.

OTHER VINEGAR PICKLES AND RELISHES

Many kinds of fruit and vegetable pickles are produced commercially.

Onions.—Small onions are first trimmed and peeled. They are generally stored in several changes of water for 3 or 4 days and are then, in some pickling plants, placed in brine strong enough to prevent fermentation, *i.e.*, about 60° (15 per cent salt), and stored until they have become translucent or until used for pickles. The brine is strengthened by addition of salt as required. The salt is leached from the onions with warm water before they are placed in vinegar. Onions are also prepared for pickling by fermentation in brine, of 10 per cent salt (40° salometer), as described earlier in this chapter for cucumbers.

Green Tomatoes and Mango Peppers.—These are usually handled in the same manner as cucumbers.

Cauliflower.—Cauliflower in some factories is placed at once in a strong brine, 60° salometer, and fermentation prevented by maintaining

the brine at this concentration until the cauliflower is cured, but Le Fevre recommends that cauliflower be cured in a 10 per cent brine (40° salometer) and prepared for the vinegar in the same manner as cucumbers.

String Beans.—These are usually cured in barrels after mixing with about 60 lb. of salt per 50-gal. barrel. The salt withdraws juice from the beans to give a strong brine. The beans may also be cured by fermentation in brine in the same manner as cucumbers.

Small Peppers.—Small peppers for tabasco sauce, etc., are fermented in wood in brine of about the same concentration as that used for cucumbers. They are also packed fresh in vinegar.

Processing and Addition of Vinegar.—These various vegetables after curing in brine are prepared and stored in vinegar in much the same manner as described elsewhere for cucumber pickles.

Sweet Fruit Pickles.—Peaches, pears, figs, watermelon rind, and grapes are often prepared as sweet pickles. We have found the following method satisfactory. The fruit is cooked in water or in dilute syrup until tender; is then boiled a short time in a syrup of sugar 24 lb., water 2 gal., vinegar 1 gal., and 1½ oz. each of whole cloves, stick cinnamon, and ginger; and is allowed to stand overnight. The syrup is drawn off and concentrated to a boiling point of about 219 to 220°F. and returned to the fruit. The fruit and syrup are heated to boiling and sealed boiling hot in jars or cans.

Also fruits are often canned in a syrup of 40° Brix containing about 1 gal. of 100-grain vinegar to 9 gal. of syrup. The syrup is spiced as described above. The fruit is canned, exhausted, sealed, and processed in the usual manner. Type L cans should be used to minimize corrosion. This product is increasing in popularity. Whole lye-peeled peaches are canned in this manner in California (see Chap. XI).

RELISHES

Most commercially prepared relishes are prepared from or contain appreciable amounts of pickled vegetables. Familiar examples of relishes are chowchow, piccalilli, Mexican hot, and mustard pickles (for recipes and formulas see references at end of this chapter).

SAUERKRAUT

"Kraut" is made in practically every vegetable-growing section of the United States and Europe by a process which is very simple and which can be conducted on either a factory or household scale. It affords a convenient means of conserving surplus cabbage during periods of temporary overproduction.

Coring and Shredding.—Only sound firm heads should be used. The outer leaves are removed by hand, and the core is reamed from the head by a rapidly revolving conical knife. (In some factories the core is not removed.) The cored cabbage is cut into thin shreds by thin, curved knives attached to a revolving metal disk about 3 ft. in diameter housed in a vertical metal cylinder into which the heads of cabbage are fed. The sliced cabbage falls on a conveyer which carries it to the fermenting tanks.

Salting.—Cabbage is converted into sauerkraut by a lactic acid fermentation, the presence of a moderate concentration of salt being necessary to reduce the growth of spoilage organisms and to promote the growth of lactic acid bacteria. A great deal of research has been conducted on the bacteriology of kraut making by Peterson, Fred, and others at the Wisconsin Agricultural Experiment Station (see references at end of chapter).

The usual proportion of salt is $2\frac{1}{2}$ per cent by weight. The salt is well mixed with the shredded cabbage as the tank or other container is filled.

Large circular wooden vats are used for commercial fermentation and storage, and heavy pressure is applied to the cabbage by a false wooden head.

Fermentation.—The pressure and salt extract juice from the cabbage, and a brine, which completely covers the cabbage, is soon formed. Bacteria and yeasts develop rapidly, and gas evolution is vigorous during the first stages of fermentation.

Although yeasts are present in considerable numbers and may produce small amounts of alcohol, particularly during the initial stages of the fermentation, the predominant organisms are lactic acid formers; *Bacillus coli* is always present and is responsible for considerable gas formation, but it is present as a contamination, and its activities result in injury rather than in benefit to the quality of the kraut. Butyric acid bacteria are also highly undesirable. If the development of yeasts, *B. coli* and butyric organisms can be prevented, or at least reduced to a minimum, the quality of the product will be improved correspondingly. The Wisconsin investigators found that most of the organisms were rod forms with relatively few coccus forms. The majority were Gram positive and catalase negative. About two-thirds formed gas from dextrose and many formed mannitol from levulose. Most of the acid formed was lactic. Some acetic acid is formed. Pederson at the New York Experiment Station has also studied kraut fermentation.

Le Fevre recommends the addition of pure cultures of selected lactic acid organisms, as a result of an improved product obtained by the use of pure cultures in his commercial-scale experiments.

The organisms were grown in sterilized cabbage, and this culture in turn was used for the inoculation of tanks of shredded cabbage. He believes that tanks started with pure cultures could be used for the inoculation of subsequent tanks, as is done in the fermentation of vinegar stock, wine, etc., and states that pure cultures are used regularly and with marked success in Europe. Suitable cultures may be had through the Department of Bacteriology of Wisconsin University, Madison, Wis.

A temperature of 65°F. is the optimum for quality in kraut fermentation. If the cabbage is cold when shredded, it is desirable to warm it to 65 to 70°F. in the tanks and to warm the fermentation room, if it is very much below 65°F.

The acidity rapidly increases during fermentation and frequently reaches 1.8 per cent expressed as lactic acid. Cabbage contains both ordinary sugars and mannite, which are all fermented to form lactic acid, carbon dioxide, ethyl alcohol, and other fermentation products.

Care after Fermentation.—After fermentation is complete the tanks should be sealed to exclude air, the presence of which permits molding, growth of film yeasts, and bacterial spoilage. Where a liquid covering only is used, this must be skimmed frequently to prevent excessive growth of the destructive film yeast.

Discoloration of Sauerkraut.—Two common forms of discoloration are recognized. One of these is the development of a pink color, the other of a brown color.

The pink color is frequently caused by growth of a pink yeast. Fred and Peterson have made an exhaustive study of this problem and have found normal sauerkraut and pink sauerkraut from the same factory to have the following compositions:

Analysis	Normal sauerkraut	Pink sauerkraut
Water	90.600%	88.000%
Volatile acid as acetic	0.247%	0.255%
Fixed acid as lactic	1.026%	1.426%
Alcohol as ethyl alcohol	0.727%	0.978%
Yeast cells per cubic centimeter	3,600,000	91,000,000

The pink sauerkraut contained a very large number of yeast-like cells from which several strains of pigment-forming yeasts were isolated. When inoculated into shredded cabbage, positive results were obtained.

The brown discoloration of sauerkraut usually occurs after removal of the kraut from the vat and is apparently an oxidation phenomenon. Prompt use or canning of the sauerkraut after opening the vat will avoid browning.

Canning.—There is a good demand for canned sauerkraut, since the canned product is in convenient form for shipment and use and is not so subject to deterioration and spoilage as the bulk sauerkraut.

The sauerkraut used for canning is ordinarily not cured for so long a time as that to be sold in bulk, as the canner desires a product of lighter color and lower acidity than the bulk sauerkraut.

It is heated to boiling in steam-jacketed kettles and is packed hot into cans in its own brine (hot fresh brine being added if necessary). The

Fig. 95.—Heating sauerkraut for canning. (*Courtesy of The Pfaudler Co.*)

cans are sealed and, in some plants, sterilized under steam pressure. In other plants the kraut is heated in jacketed glass-lined kettles, drained, and canned. The cans are filled with the hot juice, given an exhaust, sealed, and processed a short time in steam; long enough for the contents to reach 180°F. The high acidity of the sauerkraut facilitates sterilization, but heat penetration is slow.

Some loss of canned sauerkraut occurs from the development of hydrogen gas by action of the acid of the sauerkraut on the tin plate. A freshly opened can of sauerkraut possesses a disagreeable odor, but this odor disappears during cooking. Bacterial spoilage is very rare. An excellent reference on kraut is Le Fevre (1928).

PRESERVATION OF OTHER VEGETABLES BY SALTING AND FERMENTATION

In European countries, particularly Holland and Belgium, many varieties of vegetables are preserved commercially and in the home by

salting and by fermentation in brine. During the World War these methods were widely advocated by the U. S. Department of Agriculture and State Colleges of Agriculture for use in the home to conserve the surplus of war gardens and to conserve tin plate.

Practically all vegetables can be preserved by mixing with one-fourth their weight of salt or by lactic fermentation in a 5 per cent brine [for further details see Round and Lang, and Joslyn and Cruess (1933)].

GREEN OLIVES

Spain produces large quantities of pickled green olives, the United States importing from that country approximately twice as many gallons of green olives as the quantity of ripe olives produced in California.

FIG. 96.—Casks of green olives in yard of Olmeda Company, near Seville, Spain.

Varieties.—The Sevillano (Queen) is the largest and most popular olive used for green pickling, and the Manzanillo is second in importance. Both varieties have been described in Chap. XII.

Harvesting.—The olives are allowed to attain approximately full size but are gathered before they have begun to develop color or have softened. Bruising is avoided, and the fruit is placed in the pickling vats as promptly as possible.

In some olive sections of Europe if the olives are allowed to remain on the tree too long, they will become infested with the larvae (maggots) of the olive fly.

Lye Treatment.—The olives are placed in shallow vats and covered with a dilute sodium or potassium hydroxide solution (2 per cent sodium or potassium hydroxide) at room temperature. This solution is allowed to penetrate about two-thirds, but not completely, to the pits of the fruit.

If the lye solution is too strong or too prolonged, all of the bitterness is removed; the flavor, texture, and color of the finished pickles are apt

to be inferior. By removing the lye solution before it has completely reached the pits, a small amount of untreated bitter flesh remains and imparts a pleasing flavor to the pickled olives.

Washing.—The lye is then removed, and the olives are covered with water, which is changed several times daily until the fruit is free of lye. Washing will normally require about 2 days.

Fermentation.—The olives are stored in barrels or large casks in a brine of about 11 per cent salt (44° salometer) in which lactic acid fermentation develops in much the same manner as in dill pickles. The concentration drops to 28 or 30° salometer during fermentation. The barrels are completely filled with the brine and sealed except for a small vent for escape of gas. In some cases the barrels are placed in the sun in order to elevate the temperature of the brine and promote fermentation; in California they are often stored in a warm room. Brine of 28° salometer is added frequently to keep barrels full. In some cases spices are added to the brine in small amounts to improve the flavor. When gas production ceases, the barrels are sealed. It is usually desirable to add 1 to 2 per cent of dextrose (corn sugar) to the brine during fermentation in order to promote high acid production. Unless this is done, in California at least, spoilage ("zapatera") with development of a "sagey" off odor may occur. The pH value must be maintained below 4 for good keeping of the barreled olives. Frequent titrations of total acidity and pH determinations are necessary.

Packing.—The olives are packed in glass or in kegs, in fresh brine. They are rinsed previously to remove adhering sediment. The brine is, however, brought to about 7 per cent salt (28° salometer) and ¼ to ½ per cent of lactic acid added if needed. The olives usually are not sterilized or pasteurized but keep more satisfactorily if pasteurized at 140°F. (for further details see Pickling of green olives, *University of California, Agricultural Experiment Station, Bulletin* 498).

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CHAPTER XXVI

OLIVE AND COCONUT OILS[1]

Olive oil has been the principal fat used in the diet of peoples of the Mediterranean countries since Biblical times. Although most of the olive oil produced in Spain, France, Italy, and other olive-growing countries is consumed in those countries, a considerable amount is exported to America, England, Germany, and other countries which do not produce enough olive oil to supply their own needs.

Coconut oil or "copra" oil is used in enormous quantities in the manufacture of soap and in the preparation of imitation butter; England, Germany, France, and the United States being the largest users of this oil.

OLIVE OIL

In Europe olives are grown primarily for oil and pickled olives are of secondary importance, whereas in California the fruit is grown for ripe pickling purposes, and only the cull fruit is used for oil making. Consequently the varieties generally grown in Europe are those found best for oil, while in California those best for ripe pickling are grown.

Harvesting.—Olives to be used for oil can be handled somewhat less carefully than those intended for pickling and can often be knocked from the trees with poles and caught on sheets spread on the ground. This method, however, is objectionable because it injures the bearing wood of the tree. Special wooden toothed rakes are better than poles for the purpose.

If the olives are to be crushed within a few days, slight bruising does not reduce their value for oil.

Leaves, in so far as is feasible, should be excluded, because during pressing there are extracted from them compounds which injure the quality of the oil.

Olives for oil should be harvested at full maturity. Unripe olives are low in oil and yield an oil deficient in flavor, while overripe olives are apt to contain an excessive amount of solid fats (stearin and palmitin) which cause the oil to become cloudy or to solidify in the bottle or can during cold weather. In California the fruit is harvested for oil from about Nov. 15 to Jan. 1.

[1] See also Chap. XXVII.

Storage of the Olives.—It is usually impossible in most olive oil factories to crush and press the fruit as rapidly as it is received.

The more carefully the olives are harvested, the better and longer they will keep. Bruised and broken fruit molds and ferments quickly. Molding is a more serious defect than fermentation because it is more difficult to rid an oil of a moldy than of a fermented flavor.

In Europe often the fruit is placed in large bins or in large heaps on the floor. Fermentation by bacteria occurs in the tightly packed fruit; the olives give up much of their moisture and become shriveled in appearance. The temperature rises because of the heat generated by the fermentation, and there develops a peculiar "silage" odor and flavor which persist in the oil.

Olives are in some cases stored in shallow layers on large wooden trays where circulation of the air prevents mold growth and partially dries the fruit, but the method is too expensive for general use.

In Spain it is said that oil olives are sometimes preserved by mixing the fruit with a small amount of dry salt in bins. The salt is for the purpose of preventing mold growth and undesirable bacterial fermentation. However, the author failed to observe this procedure on a visit to olive oil factories in that country in 1924; although storage in bins or in heaps was common practice.

In California olives to be used for oil are generally stored in brine, as for pickling (see Chap. XII), or in lug boxes stacked in a cool location.

Washing.—It is desirable that the fruit be washed to remove adhering soil and leaves before crushing. Sprays of water can be used to advantage for this purpose.

Sanitation in the Olive Oil Factory.—Olive oil absorbs odors and flavors rapidly, and once acquired by the oil they are extremely difficult to remove or correct. Press cloths become rancid unless kept scrupulously clean. Press cake (pomace) soon becomes moldy, and the odor may be absorbed by oil stored in the vicinity. Crude oil, smoke, and other odoriferous materials should not be allowed to contaminate the oil. Floors, bins, conveyers, filters, and other equipment with which the fruit or oil comes in contact must be kept clean and free from rancidifying oil. Washing floors and equipment with hot sodium carbonate solution occasionally will remove rancid oil or other adhering vegetable matter. Press cloths should at the end of the season be boiled with such a solution to remove all oil.

First Crushing.—In California the olives are crushed between revolving-steel rolls of the type used for the crushing of barley; the seeds of the fruit for the most part escape crushing.

The fruit is elevated to a hopper above the crusher rolls and, after passing through the crusher, is collected in press cloths spread beneath

the rolls (see Fig. 97). In Mediterranean countries often the first, as well as subsequent, crushings are by edge runner.

First Pressing.—The first pressing is made in a rack and cloth press similar in appearance to the apple press described in Chap. XV. Very heavy folded cloths containing the crushed fruit to a depth of about 3 in. are placed between woven-metal racks or heavy wooden racks (see Fig. 97).

Pressure is applied by means of a hydraulic or a gear-driven press. The pressure indicated in the cylinder head on the press during the first pressing is 400 to 500 lb. per square inch.

Fig. 97.—At left, building up crushed olives in cloths and racks. At right, pressing.

The first pressing extracts most of the juice and a small proportion of the oil. The oil obtained by the first pressing is known as "virgin" oil and is considered superior in flavor and general quality to that obtained by subsequent pressings.

Second Crushing.—The pomace from the first pressing is placed in a machine known as an edge roller, consisting of a large cast-steel bowl in which revolve two heavy steel or stone wheels (see Fig. 98). The pulp is thoroughly crushed and some of the seeds are broken.

Second Pressing.—The crushed fruit is again placed in press cloths and subjected to a second pressing, usually in a more powerful press than that used for the first pressing. The pressure indicated on the pressure gauge on the hydraulic press cylinder is usually about 1,500 lb. per square inch.

The second pressing extracts most of the oil, the oil and juice being collected in a tank below the press and pumped to settling tanks. First and second pressing oils are usually combined.

Third Crushing.—The pomace from the second pressing is broken up, again placed in the edge runner and a small amount of hot water is added to facilitate crushing and pressing. Most of the seeds are broken and the kernels crushed.

Third Pressing.—A relatively small amount of oil is obtained by the third pressing, and it consists of oil from the flesh admixed with considerable oil from the seeds. The seed oil is inferior in quality to the oil

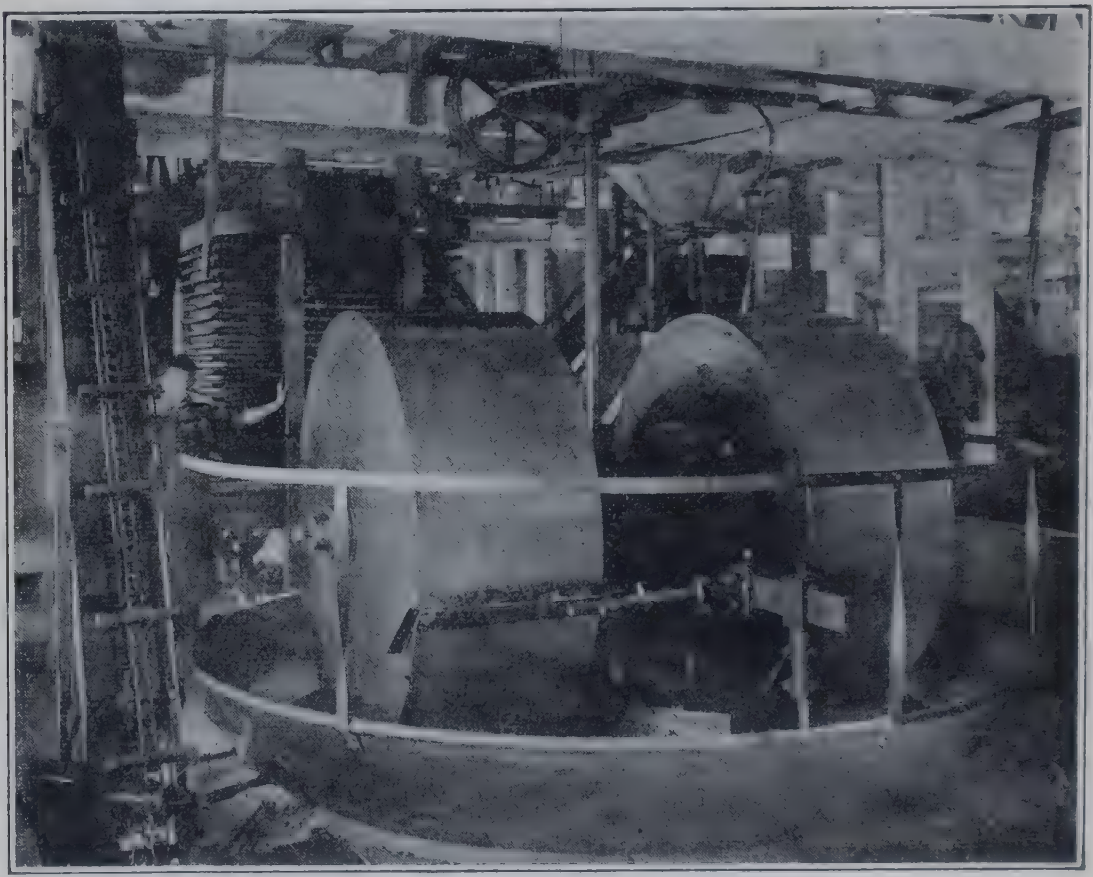

Fig. 98.—Edge runner for grinding pressed olives.

obtained from the flesh and contains an enzyme which hastens rancidification. The hot water added at the time of the third crushing melts the solid fats, and the expressed oil also carries a larger percentage of these solid fats than does oil from either the first or second pressing.

For these reasons the oil obtained by the third pressing is usually not mixed with that from the first and second pressings.

European Methods.—In European countries press cloths made of tough esparto grass fiber are used, and pressure is often applied by means of a screw press operated by hand.

Much of the European oil is made in small factories operated by growers, and the oil so made is often very inferior because of molding or fermentation of the fruit before crushing and pressing as well as from

carelessness in handling the expressed oil. The oil is delivered to centrally located refineries where any disagreeable odors and flavors are removed and the refined oils blended with high-quality oils.

The Lucca and Bari districts in Italy are particularly famous for oil refineries. Marseilles in France and the Seville and Tarragona districts in Spain are also important olive oil refining centers.

Other Methods of Extracting Olive Oil.—Shaw states that in Algiers and other oil-producing countries of the Mediterranean region, oil is recovered in some factories by separating the seeds from the pulp, by grinding the pulp finely, and by separating the pulp, juice, and oil by use of a centrifuge; although the writer was informed in Europe in 1924 that this method had not proved commercially important.

In California the Burt brothers have developed a process in which the olives are passed through a continuous press or a tomato pulper equipped with a very heavy screen to separate the pulp from the seeds. The resulting purée is mixed with warm water or brine, and the oil is separated from the juice and pulp in a high-speed cream separator.

According to Bioletti and Oglesby, in a process tested experimentally in Europe, the seeds are separated from the pulp, the pulp is finely ground, mixed with warm water and subjected to a vacuum. The oil is said to collect on the surface of the mixture and can be recovered by skimming.

A continuous olive oil press similar in design to the oil expeller used for the extraction of oil from copra and other dry oil-bearing materials can be used satisfactorily, if the fruit is dried before pressing. In the Acapulco process of Spain the olives are pulped, separated from the seeds, and the resulting purée is rubbed mechanically against a very fine screen that separates the oil by capillary action. It has not become of commercial importance, however.

Separation of Oil and Black Liquor.—The oil and juice ("black liquor") are pumped from the oil-pressing tank to tall cylindrical tin or galvanized-iron tanks to permit settling and separation of the juice and oil.

The settling tanks hold 300 to 800 gal. each and are equipped with conical or sloping bottoms so that the oil and juice can be separated sharply by drawing off the juice through a faucet. Some factories use a tank in which the oil and juice are separated continuously immediately after pressing, the juice flowing continuously from an outlet at the bottom of the tank and the oil flowing from an outlet near the top. In practically all modern olive oil plants the black liquor and oil are separated continuously by a centrifugal clarifier.

Washing the Oil.—Freshly expressed olive oil contains a considerable amount of bitterness, which is more soluble in water than in oil, and on

this fact depends the method of removal of the bitterness from the oil.

In the simplest form of oil-washing device the oil is placed in a tin or galvanized iron tank and warm water is sprayed on the surface of the oil, dissolving the bitterness as it flows downward. The process can be made continuous. In some factories the oil is sprayed upward into a tank of warm water and may be recovered by skimming or may be allowed to overflow from the tank into a suitable conduit. Theoretically this method should be more effective than spraying the water into the oil, because each oil droplet is surrounded by an excess of water when the oil is sprayed upward into water. The water used is maintained at 90 to 100°F.

Preliminary Settling.—The washed oil is cloudy and contains a considerable quantity of pulp and some emulsified water. Settling for 10 or 12 days in tall cylindrical tanks permits deposition of much of this suspended matter and separation of some of the excess solid fats. The settlings, "foots," can be removed by drawing off through a faucet. The foots can be sold for soap stock or filtered to recover an appreciable percentage of oil.

First Filtration.—The settled oil is cloudy, contains some water and should be filtered before storage, to remove the water and solid impurities. In one California factory this is done by mixing the oil with infusorial earth and filtering through canvas filter bags. Filtration is rapid and the equipment is inexpensive. A fairly clear oil is obtained and most of the water and solid impurities are removed.

A filter press can be used successfully for the first filtration if so desired, particularly if infusorial earth is mixed with the oil. The filter press may be made of iron or galvanized iron as oil does not attack these metals.

Aging.—Like new wine, fresh olive oil is not pleasing in flavor and must be aged before it is ready for bottling or canning.

In California the oil is placed in galvanized iron or tin tanks holding about 1,000 gal. each.

In some European and Algerian factories glass-lined concrete tanks or large earthenware pots or tanks are used for storage of the oil during settling. The oil tanks should be constructed of materials that will not absorb the oil.

Final Filtration of the Oil.—In most California factories the oil is filtered through folded filter paper in tin funnels, as many as 500 to 600 filters being used in a single factory. This method of filtration is slow and costly of labor but produces a brilliantly clear oil.

Several factories in California are equipped with filter presses in which pieces of heavy filter paper are used in the filter frames. The oil is forced through the filters by a pump or by gravity. Filtration is facilitated and

the clearness of the filtrate increased if a small amount of infusorial earth is added to the oil before filtration.

Removal of Excess Color.—Often olive oil is too dark in color to be merchantable. The excess color can be removed by mixing the oil with finely ground bone black or vegetable decolorizing carbon or with fullers' earth. Decolorization is hastened by heating the mixture to 175 to 190°F. for 30 to 60 min. before filtration. If the oil becomes too light in color, it may be blended with oil of darker color to obtain the desired tint.

Refining of Spoiled Olive Oils.—Olive oil made from moldy or fermented fruit frequently possesses a disagreeable odor or flavor, or both. Oil frequently becomes rancid, *i.e.*, the olein decomposes into free oleic acid and glycerin, with the development of the well-known odor and flavor of rancid oil. It is possible in most cases to remove objectionable odors and flavors and to neutralize and remove free fatty acids. The treatment will vary with the character and the degree of decomposition.

Removal of Free Acid.—Oil which has merely become rancid without the absorption of foreign odors or flavors can usually be rendered edible by neutralization of the free fatty acid with sodium carbonate or sodium hydroxide. The hydroxide is used in European refineries.

From the titration of the free fatty acid, the amount of alkali required to neutralize the acidity of the lot of oil requiring treatment can be calculated. The required amount of carbonate or dilute hydroxide can then be mixed with the oil, the mixture heated gently to facilitate neutralization, and the neutralized oil cooled and filtered. Approximately 5.3 grams of sodium carbonate will be required for each 28.2 grams of free oleic acid. Some water must also be added to enable the reaction to occur.

Removal of "Off" Odors and Flavors.—If the oil has been made from moldy or fermented fruit or has acquired disagreeable odors or flavors in other ways, the treatment described above will not be adequate. Usually adding 1 to 2 per cent of vegetable decolorizing carbon to absorb disagreeable flavors, heating to 190°F., and washing with a stream of carbon dioxide for 2 to 3 hr. will remove objectionable odors and flavors.

In European refineries it is customary to treat the oil with superheated steam under a vacuum, a treatment that will usually remove odors which cannot be removed by other means. Some oils are deodorized by heating at atmospheric pressure and treating with a stream of air for several hours. Before deodorizing, the oils are neutralized with 10 per cent sodium hydroxide and decolorized with fullers' earth or carbon and filtration.

Properties of Olive Oil.—Olive oil consists of approximately 70 per cent olein (the triglyceride of oleic acid), $C_3H_5(C_{17}H_{33}CO_2)_3$, approximately 27 to 28 per cent palmitin, $C_3H_5(C_{15}H_{31}CO_2)_3$, some stearin, $C_3H_5(C_{17}H_{35}CO_2)_3$, and a small amount of linolein. Stearin and palmitin

are solid fats and are the cause of the turbidity of olive oil during cold weather.

The specific gravity of olive oil is 0.914 to 0.918, and its saponification value is 190 to 195. Good-quality oil solidifies at approximately 2 to 5°C.; oils containing an excessive amount of solid fats solidify at higher temperatures. The iodine value for olive oil is 79 to 93. The refractive index at 15°C. is 1.47.

Olive oil is often adulterated with cottonseed and other cheap oils but added cottonseed oil can usually be detected by the Halphen test, which consists in heating the oil with a mixture of equal parts of amyl alcohol and carbon bisulfide, the latter containing 1 per cent of free sulfur. An orange-red coloration develops if cottonseed oil is present. Characteristic tests are also available for the detection of other edible oils used in adulterating olive oil.

Yield of Oil.—From 35 to 45 gal. of oil per ton is obtained in California from the Mission variety and less from other varieties.

By-products.—The pomace from olive oil manufacture contains an appreciable amount of oil. Analyses of a large number of samples from oil mills in California by A. W. Christie and the writer demonstrated the presence of 7 to 16 per cent of oil in the air-dried pomace. This corresponds to about 19 to 42 gal. of oil per ton of pomace. The average oil content was approximately 10 per cent. Most of the pomace in California is utilized for fuel, no attempt being made to recover oil.

It was found that most of this residual oil could be recovered by extraction with various fat solvents, such as ether, benzene, chloroform, carbon bisulfide, and gasoline. A solvent-extraction plant is now operating.

In European countries in which olive oil is produced, the pomace is dried and then extracted with a volatile solvent. The oil so recovered is refined and sold for soap manufacture or other industrial purposes. It is stated that some of this solvent oil, when highly refined, is blended with oil obtained by pressing and is sold as edible oil. Trichloroethylene is a satisfactory, noninflammable solvent and is used commonly in France. In Spain and Italy carbon disulfide is the usual solvent, in spite of its extreme inflammability and explosiveness. Oil recovered by this means is known in the trade as "sulfur oil" and is used for soapmaking.

COCONUT OIL

The United States imports in excess of 500,000,000 lb. of copra (dried coconut meat) annually, and the world production of copra is about 1,500,000,000 lb. The copra is used for the production of coconut oil, one of the principal oils used in the manufacture of soap and oleomargarine.

Harvesting and Drying Coconuts.—Selected varieties of coconut palms are grown in large plantations in the tropics. Natives harvest the fruit and transport it to centrally located drying depots.

Usually the nuts are cut or broken open by hatchets, and the juice ("milk") is generally wasted, although it contains fermentable sugar and can be used as a source of alcohol or vinegar or can be condensed to a syrup.

The fruit is spread on trays in the sun to dry. During drying, the meat loses about 50 per cent of its weight and becomes loosened from the shell. When dry, the meat and shell are readily separated. In some drying depots the meat is separated from the shell before drying.

The dried meat "copra" is shipped in bulk by vessel to American or European ports.

Sun drying results in decomposition of a large proportion of the oil by fungi and by the action of sunlight. Twenty per cent of free fatty acid in the expressed oil is not uncommon. Decompositon often occurs, also, during water shipment, because of conditions favorable to mold development in the damp holds of ships.

Some copra is made by drying the meats by artificial heat but usually the driers are poorly designed and smoky. Undoubtedly there is need for the installation of efficient, modern dehydraters for drying copra for oil purposes. Drying of coconut for culinary purposes is conducted in well-built and carefully operated driers, but such equipment is probably too costly for drying copra for soap-oil manufacture.

The yield of copra is approximately 1,200 lb. per ton of fresh coconut meat.

Composition of Copra.—Copra contains about 60 to 65 per cent of oil. That containing more than 6 per cent moisture rancidifies quickly.

Removal of Refuse.—At the oil factory the copra passes over a broad belt where large pieces of shell, wood, stones, etc., are removed by hand. A magnet at the end of the belt removes nails, bolts, and other scraps of iron which if not removed might wreck the shredding machines.

Shredding.—To facilitate pressing, the copra is shredded mechanically or ground between fluted rollers.

Heating.—The shredded copra is heated by steam to soften the oil, since coconut "oil" (palmitin) is at normal temperatures a solid fat.

Pressing.—The heated material is pressed in an expeller, a heavy-duty continuous screw press, which extracts the oil to the point where the press cake contains about 8 per cent of oil.

The cake is ground, is again heated, and is then pressed in cloths in a hydraulic press.

From 1,100 to 1,300 lb. of oil per ton is recovered by the two pressings.

Disposal of Press Cake.—The press cake, amounting to about 700 to 800 lb. per ton of copra, is high in protein and feeding value. It is ground to a coarse meal, sacked, and sold to dairymen and other stock raisers.

Uses of Edible Coconut Oil.—Deodorized refined oil is sold to manufacturers of imitation butter ("nut oleomargarine") who "churn" it with

sour milk, cool, and crystallize it and mold it in butter forms. The oil is used also in lard substitutes.

Shipment of Oil.—The oil is usually shipped in tank cars holding about 10,000 gal. of oil each. It is pumped into the tanks while warm and solidifies on cooling. Steam is used to melt it for removal.

Refining.—The free fatty acid (often equal to 20 to 30 per cent of the total oil) is neutralized by heating with the required amount of concentrated sodium hydroxide or sodium carbonate. The resulting soap is recovered and sold to soap factories. If an emulsion forms, it can be broken by the addition of heavy brine.

The oil is decolorized by passage through steel towers filled with coarsely ground bone coal, heated with steam coils to prevent solidification of the oil. The decolorized oil is then filtered by means of filter presses. It is also in some plants decolorized with finely ground vegetable decolorizing carbon plus filtration through a filter press.

The oil may be deodorized by treatment with superheated steam *in vacuo* or by blowing the warm oil with a steam of air or carbon dioxide or by washing with ethyl alcohol.

Properties of Coconut Oil.—Coconut oil consists chiefly of palmitin, $C_3H_5(OC_{15}H_3CO)_3$, laurin, $C_3H_5(OC_{13}H_{23}CO)_3$, and myristin, $C_3H_5(OC_{13}H_{27}CO)_3$. It also contains small amounts of other oils. High-quality edible coconut oil must contain less than 0.1 per cent of free fatty acid.

The melting point of coconut oil is 23 to 26°C.; specific gravity at 100°C., 0.86 to 0.9; saponification value, 250 to 260; and refractive index at 60°C., 1.43.

At ordinary temperatures it is solid, although in very warm weather it becomes liquid and possesses the characteristic coconut flavor unless deodorized.

Coconut oil is unstable and becomes rancid more rapidly than many other vegetable oils. Various antioxidants may be added to retard rancidification, such, for example, as an extract of oat flour.

Hydrogenation.—Liquid oils can be transformed into solid fats by union with hydrogen. Thus olein (of cottonseed oil) can be converted into stearin according to the following reaction:

$$\underset{\text{Olein}}{C_3H_5(C_{17}H_{33}CO_2)_3} + 3H_2 = \underset{\text{Stearin}}{C_3H_5(C_{17}H_{35}CO_2)_3}$$

This reaction is known as "hydrogenation."

Hydrogenation is accomplished by heating the oil, usually in an autoclave under pressure, to 150 to 250°C. with hydrogen gas and a finely divided catalyzer, such as specially prepared nickel or platinum.

Hydrogen used for oil treatment must be very pure and free from catalyst "poisons" (inactivators), such as hydrogen sulfide, arsenic,

etc. Electrolytic hydrogen from the electrolysis of water is the purest hydrogen gas obtainable but is more expensive than that obtained by reducing water vapor over pure spongy iron.

Most oils lose practically all their odor during hydrogenation; thus fish oil loses much of its "fishiness" and copra oil most of its coconut odor and flavor.

Oils to be hydrogenated must be practically free from free fatty acid (for details of hydrogenation see Ellis; also Hilditch).

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CHAPTER XXVII

UTILIZATION OF WASTE FRUITS AND VEGETABLES AND DISPOSAL OF WASTES

In the canning, drying, and preserving of fruits and vegetables there accumulate peels, cores, pits, vines, cobs, and other waste materials which must either be utilized in some manner for by-products, fed to livestock, or disposed of as garbage.

The utilization of fruit pits has become an important industry in California and at present nearly all of the apricot pits from the drying and canning industries are converted into valuable by-products.

Character of Fruit and Vegetable Wastes.—The more important wastes are the following:

1. Fruit wastes:
   a. Peels, cores, and trimmings.
   b. Pits from apricots, cherries, and peaches. Cull nuts.
   c. Grape seeds, stems, and skins (pomace).
   d. Cull fruit from fresh-fruit packing houses.
   e. Overripe and blemished fruit from canneries, driers, etc.
2. Vegetable wastes:
   a. Tomato seeds, skins, and trimmings.
   b. Asparagus waste from canning.
   c. Cobs and husks from corn canning.
   d. Vines and pods from pea canning.
   e. Wastes from canning or drying miscellaneous vegetables, such as spinach, pumpkin, sweet potatoes, and beans.

Cereal wastes, such as cottonseed, corn germs, and wastes from fish and meat packing, could also be added to the list, but these do not come within the scope of this book.

FRUIT BY-PRODUCTS

The utilization of waste and cull fruit in the preparation of certain products is discussed in other chapters. Among the products made from such fruit may be mentioned jams, jellies, juices, and vinegar (see Chap. XV, XVI, XVII, and XVIII).

Fruit Peels and Cores.—A large part of the cores from apple canneries and dryers are now utilized for the manufacture of vinegar or for jelly stock. If this material is to be used for vinegar, it should be crushed and

pressed within a few hours after the fruit is peeled, so that loss of sugar does not result by wild yeast fermentation and an excessive amount of acetic acid is not developed by the activitity of acetic acid bacteria (for details of vinegar manufacture see Chap. XXIV).

Jelly Base.—Apple cores and peels are often dried and sold to jelly factories. The dried material is refreshed in water and boiled to extract pectin. The resulting extract is combined with various fruit juices or pulp in preparing cheap jellies and jams. The dried waste is also used as a raw material for the preparation of powdered pectin and pectin concentrates (see Chap. XVII for further details).

Utilization of Pineapple Waste.—As previously outlined, pineapple peels and cores from canning are now utilized in several ways (discussed in Chap. XI) or for vinegar.

Much of the juice is fermented for the manufacture of alcohol, denatured by the addition of wood alcohol and ether. Ether has been added to the denatured alcohol for the purpose of rendering the mixture more explosive for use in automobile engines. The pressed peels and cores are dried and used for stock feed. The juice is also decolorized and mixed with cane sugar syrup for use in canning pineapple. Citric acid is recovered from the juice by neutralizing with calcium carbonate and subsequently treated as in making citric acid from lemon juice.

Pineapple cores are candied and exported to the mainland of the United States for the use of confectioners.

Fruit Pits.—In the canning of peaches, apricots, and cherries, a large quantity of waste pits is obtained. These are utilized in Germany and the United States for the manufacture of a fixed oil, bitter almond oil, and macaroon paste.

Apricots, prunes, cherries, peaches, and almonds are botanically closely related, all being members of closely related genera of the *Drupaceae* family. The fixed oils and bitter almond oil obtained from the kernels of these various fruits are practically identical in composition, the bitter principle in all cases being amygdalin.

Separation of Pits and Kernels.—The kernels contain the most valuable constituents of fruit pits, and the first step in their utilization is the separation of the kernels from the shells. Apricot, bitter almond, cherry, and prune pits are easily crushed between heavy iron rollers so adjusted that the pits are broken and the kernels not crushed. The broken pits and kernels drop from the crusher into a tank of brine of such concentration that the kernels float and the shells sink.

The kernels are skimmed from the surface of the brine by a mechanical device and are sprayed with water to remove excess salt. They are then dried, cleaned by grain-cleaning machinery to remove shriveled kernels and other refuse, and sorted by hand on belts to remove pieces of shell,

moldy kernels, and other objectionable material not removed by the cleaning machine.

Yields of Kernels.—Apricot pits yield about 23 to 24 per cent of kernels and peaches about 7 per cent. Peach pits are difficult to crack, and the kernels are difficult to recover, a large percentage of the kernels being poorly developed or dried and devoid of oil. Cherry pits according to Rabak yield about 28 per cent of kernels. Prune pits yielded about 10 to 15 per cent of kernels in laboratory tests made at the University of California.

Expressing the Fixed Oil.—The fixed oil is the most valuable constituent of these waste pits. It is generally recovered by pressure but may also be extracted by the use of volatile solvents. If solvents are used, the resulting oil is usually only fit for soap stock.

The kernels are coarsely ground to facilitate pressing, heated to near the temperature of boiling water by steam or by passage through a steam-jacketed tube, and pressed by a continuous press known as an expeller or by a press in which cloths and racks are used as in the pressing of olives.

Expressing Oil by Expeller.—The continuous press is inexpensive to operate but gives a cloudier oil and lower yield than pressing between cloths and racks; nevertheless it is the one generally used in expressing oil from seeds. It consists of a horizontal, perforated, heavy metal cylinder fitted with a screw conveyer. The kernels enter the press through a hopper at one end of the cylinder and are conveyed by means of the screw toward the opposite end of the cylinder and over a heavy metal cone projecting into the cylinder. As the diameter of the cone increases, the pressure applied to the kernels increases. The pressure can be adjusted by decreasing or increasing the size of the outlet and the distance between the walls of the cylinder and the cone. The press cake passes out over the cone, and the oil flows through perforations in the floor of the press cylinder. The press cake is ground and pressed a second time to recover as much of the oil as possible.

Use of Hydraulic Presses.—In using hydraulic presses the kernels are prepared as for pressure in the expeller, the heated, ground kernels are packed in heavy press cloths usually made of camel's hair; steel plates are placed between each pair of cloths; and a pressure of 3 to 5 tons per square inch is applied. The press cake should be reground and pressed a second time.

Yields.—From apricot kernels a yield of at least 33 per cent of oil should be obtained, from peaches about 25 per cent, and from cherries and prunes about 30 per cent.

Refining the Fixed Oil.—The oil contains considerable solid material, such as particles of kernels and kernel skins. These can be removed by screening or coarse filtration.

The raw oil is often high in free fatty acid, dark in color, and rancid in flavor, and it is necessary to refine it. This can be done by treatment with a small amount of sodium carbonate to neutralize the free acid, by the addition of a decolorizing agent such as vegetable decolorizing carbon or fuller's earth, and by heating with steam *in vacuo* to volatilize objectionable odors.

Titration of the acidity and laboratory trials with small measured volumes of the crude oil will determine the quantities of sodium carbonate and decolorizing carbon or fuller's earth that must be used. Usually 2 to 3 per cent of powdered bone black or finely ground vegetable decolorizing charcoal will be sufficient. The oil is generally not bleached water-white, but is usually decolorized only to a light straw color.

The reaction between the fatty acid and the carbonate is facilitated by the presence of about 0.5 per cent of water, and heat is necessary for the best results. In one factory in California which is no longer in operation, the mixture of bone black, sodium carbonate, oil and about 0.5 per cent water was heated to about 190 to 200°F. The mixture was then mechanically agitated, and a stream of carbon dioxide was passed through the oil to remove objectionable odors by volatilization. After several hours' treatment the oil was allowed to settle and was filtered. The finished oil was nearly colorless and was of pleasing flavor and odor.

The refined oil finds a market for use in the preparation of face creams and pharmaceuticals but is also an excellent table oil and at one time was used extensively in California in the canning of sardines.

Composition of the Fixed Oil.—The fixed oils from apricots, sweet almonds, bitter almonds, peach kernels, prune kernels, and cherry kernels are practically identical in composition. The principal compound present in these oils is olein, $C_3H_5(C_{17}H_{33}CO_2)_3$. There are also present small amounts of stearin and palmitin, both of which are solid fats.

Bitter Almond Oil from Press Cake.—The press cake remaining from the extraction of the sweet oil contains the bitter principle, amygdalin, and an enzyme, emulsin, which has the power of converting amygdalin into benzaldehyde, glucose, and hydrocyanic acid, according to the following reaction.

$$C_{20}H_{27}O_{11}N + 2H_2O = C_6H_5CH{:}O + HCN + 2C_6H_{12}O_6$$

Benzaldehyde imparts the characteristic odor and flavor to bitter almond oil and to flavoring extracts such as "wild cherry." Artificial bitter almond oil and flavoring extracts are commonly made from benzaldehyde synthesized from benzene, a coal tar product, and a bitter almond oil from fruit kernels is frequently adulterated with the synthetic benzaldehyde.

Hydrolysis of Amygdalin.—The press cake is heated with about 12 volumes of water to soften the ground kernels and to extract the amygda-

lin. The heating of the ground kernels before pressing may destroy most of the enzyme emulsin, making it necessary to add to the mixture of water and kernels freshly ground unheated kernels equal to about 10 per cent of the press cake, in order to hydrolyze the amygdalin. The mixture is warmed to a temperature of about 50°C. (122°F.) for an hour or less. Hydrolysis can also be conducted at room temperature, but at least 12 hr. should be allowed at this temperature.

If the kernels are not heated to a high enough temperature before pressing to destroy the enzyme emulsin, the press cake does not require the addition of unheated kernels to cause hydrolysis of the amygdalin. This method has been used successfully in one California oil factory.

Distillation.—Benzaldehyde boils at 179°C., and in order to separate it from the water and kernels, it is necessary to distill it from the mixture with a current of steam, which is done by placing the mixture of kernels, water, etc., in an enclosed metal tank, passing a current of steam through the mixture and condensing the vapors by a water-cooled condenser. There should not be any open outlets from the distillation apparatus within the distillation room, because of danger of poisoning from the hydrocyanic acid which distills with the water and benzaldehyde. The bitter almond oil settles to the bottom of the vessel in which the distillate is collected and can be easily separated from the water which distills with it. It contains from 2 to 4 per cent of prussic acid, and if the oil is to be used for medicinal purposes, the prussic acid is not removed.

Refining.—If to be used as a flavoring material most of the prussic acid must be removed from the bitter almond oil. This can be done by heating with slaked lime and an iron salt or by treating with sodium bisulphite. It is necessary to redistill the benzaldehyde from the reaction mixture.

Rabak (1908) obtained from peach kernels, 0.7 per cent of bitter almond oil; from apricot kernels, 1.6 to 0.8 per cent; from prune kernels, 0.3 to 0.46 per cent; and from cherry kernel press cake, 0.95 per cent. The yield from the press cake is nearly 50 per cent greater than from the fresh kernels, owing to concentration of amygdalin in the cake, by expression of oil.

Macaroon Paste.—Macaroon paste is used extensively by bakers. Although some macaroon paste is made from sweet almonds, much of this product now used by American bakers is prepared from apricot kernels.

In one method of preparing macaroon paste, the kernels are first blanched, *i.e.*, heated in water a short time to soften and loosen the skins, and are then peeled mechanically. The temperature used should be such that the emulsion is not injured. The peeled kernels are ground and heated with water at about 50°C. to cause hydrolysis of the amygdalin. The resulting benzaldehyde and prussic acid are removed by steam dis-

tillation, and the residual meal is separated from the excess water by treatment in a filter press. It can then be mixed with cane sugar and heated in a steam-jacketed kettle to remove excess water. The resulting paste is sealed hot in cans.

Another process consists in removing the skins from the kernels; heating the kernels in water to hydrolyze the amygdalin, drying the hydrolyzed kernels to expel benzaldehyde and prussic acid, and finally grinding the deamygdalinized kernels with sugar to give a paste.

Press-cake Meal.—The press cake, after grinding and distillation with steam for recovery of the bitter almond oil, can be separated by pressing from the water with which it is associated and used for a stock food. high in protein and carbohydrates. Rabak (1916) found cherry kernel press cake to contain 30.87 per cent protein, 42.13 per cent nitrogen-free extract, 8.9 per cent crude fiber and 13.1 per cent ether extract. It was richer in protein than coconut meal but contained less protein than cottonseed meal. Analyses of apricot, peach and prune kernel meals are not given, but these are probably of approximately the same composition as cherry pit meal.

The solution left in the still after distillation, according to Rabak, contains approximately 6 per cent by weight of the original press cake, which can be evaporated to dryness and incorporated with the dried and ground press cake.

Waste from Grape Juice Factories and Wineries.—In the preparation of grape juice and wine, grape stems and grape pomace are obtained as waste products. The pomace consists of the pressed skins and seeds. In most grape juice plants little effort is made to utilize these waste materials.

Stems.—Grape stems, separated from the grapes at the time of crushing, as described in Chap. XV, normally constitute approximately 5 per cent of the original weight of the grapes. Rabak and Shrader find that the Concord grape stems yield about 2 per cent of cream of tartar when chopped in short lengths or ground and extracted with boiling water. The watery extract is concentrated by boiling and allowed to cool and stand 24 hr. or longer. Cream of tartar (potassium acid tartrate) separates as crude crystals which can be purified by redissolving in water and recrystallizing. The watery extract was too low in tannin to warrant concentration.

Separating Seeds and Skins.—The pomace consists of seeds and skins which must be separated before the seeds are used for oil. Rabak and Shrader found that the separation could be made fairly satisfactorily by screening out the seeds after passing the wet pomace through a pomace picker, such as is used in the vinegar industry, and through an apple grater to break up the press cake thoroughly. The seeds fall through a ¼-in. screen, and the skins are retained.

If the pomace is dried thoroughly before screening, an almost perfect separation of the skins and seeds can be made by screening and fanning.

Drying can be economically accomplished in rotating cylinders heated by a blast of air or steam pipes.

Recovery of Oil.—The seeds are ground and the oil extracted by means of an expeller, as described for the extraction of oil from fruit kernels, and a yield of 10 to 15 per cent is reported. Yields from California grape seeds are much lower than this. More satisfactory results are obtained if the seeds are decorticated (hulled) before pressing. This is accomplished by crushing the seeds lightly between rolls and by screening and fanning to remove the hulls. The kernels may be ground and pressed or pressed direct without grinding. If decortication is not accomplished, the hulls cause excessive wear on the expeller and high percentage of crude fiber in the press cake which greatly impairs its value as a stock food.

In a California grape seed by-products factory the ground seeds are pressed in hydraulic presses between heavy cloths and steel plates.

In Europe the oil in some factories is recovered by extraction with a volatile solvent, such as benzene, gasoline, trichloroethylene, or carbon bisulfide, but it is difficult to remove all trace of the solvent from the oil, and it is generally only suitable for soap making. If trichloroethylene is used as solvent an edible oil can be prepared. Extraction with solvents is conducted in tall steel tanks, a battery of several tanks in series being used. The residue from solvent extraction with gasoline or benzene is usually not suitable for stock food and can only be utilized as a fertilizer; whereas the press cake from an expeller or hydraulic press can be used to good advantage as a stock food. Residues extracted by trichloroethylene can be made suitable for stock food. Solvent oil can be deodorized by treatment with steam *in vacuo*, but the deodorized oil is usually not of high enough quality for use as food.

Tannin from Hulls.—The hulls from the decortication of grape seeds contain a large percentage of tannin, which can be extracted by boiling with water and concentrated to a heavy syrup. Rabak and Shrader have found such a product suitable for the tanning of hides. A yield of 10 per cent of syrup containing 15.5 per cent of tannin was obtained from the hulls.

Jelly from Grape Skins.—Grape skins from Concord grapes, and the whole grape pomace as well, were found suitable for the preparation of jelly and jelly stock, by the usual methods described in Chap. XVII. An average of 24 oz. of jelly was obtained from each pound of pomace. California wine-grape pomace is not suitable for this use.

Character of Grape-seed Oil.—Grape-seed oil is a semidrying oil, resembling soybean oil in this respect, and on this account can be used in paints. If to be used as a table oil, it must be refined by treatment

with sodium carbonate or other alkaline material, to remove free fatty acids, and with bone black or fuller's earth, to remove excess color (see paragraphs on refining of olive and coconut oils in Chap. XXVI).

Value of Press Cake.—The press cake from grape-seed-oil production is suitable for stock food, although it is desirable to mix with it bran or alfalfa meal or similar material to reduce the tannin content of the mixture at the time of feeding. The press cake is very high in crude fiber, an objectionable feature from the standpoint of its value as stock food. According to Rabak and Shrader, press cake from the decorticated seeds in their experiments contained 4.48 per cent fat, 14 per cent protein, 29.7 per cent nitrogen-free extract (starch, etc.), and 43.2 per cent crude fiber, thus comparing favorably, except in crude fiber, with other seed meals in feeding value.

Use of Pomace for Stock Food.—The pomaces from grape-juice production, wine making, apple-juice production, and olive-oil making may be dried and used for stock food.

In California grape pomace from wineries and apple pomace from vinegar factories is now being dried in direct-fired rotary-drum driers. It is then ground in hammer mills and used in the feeding of livestock, particularly dairy cows. The fuel in most cases is natural gas. In one form of dehydrater the flames and heated air from the furnace enter the drying drum with the incoming wet pomace, the temperature being about 1300°F. The dried pomace and spent air (at about 300°F.) are drawn from the lower, opposite end of the drum. The drum in this case is about 60 ft. long and about 6 ft. in diameter. In another type of drum drier used for grape pomace a metal cylinder extends through the center of the main drying drum. The flame and hot gases enter this inner cylinder, pass through it to the opposite end, and are returned through the space between the two cylinders to the furnace end of the drier. This type of drier permits longer contact with the drying medium without danger of scorching the product, thus giving sufficient time for the moisture in the seeds and larger lumps of pomace to diffuse to the surface.

The pomace must be dried to less than 10 per cent moisture in order to prevent spoilage by molding and spontaneous heating. One large dairy in California is successfully using 30 per cent of the finely ground dry pomace in the cows' ration; although 15 to 20 per cent is the more common proportion.

The pomace is high in crude fiber. Its principal value is its moderate content of oil and protein. Most of the feeding value lies in the kernels or meaty portion of the seeds, as the skins, stems, and seed hulls have little digestible substance and are of value only for roughage. The average composition of five samples of the dried ground pomace from five large California wineries was as follows: ash, 5.99 per cent; crude fat

extract, 5.33 per cent; protein, 11.9 per cent; crude fiber, 35.9 per cent; and moisture 3.44 per cent. The moisture content is lower than that of the pomace as fed because the samples were taken direct from the drier and sealed in jars; while in practice the dried, ground pomace is stored in bags or bins and absorbs considerable moisture from the air. Pomace from dry wine making has greater feeding value than that from sweet wine making as it contains some sugar and other soluble food values, whereas the pomace from sweet wine making is thoroughly leached with water several times to recover residual alcohol for production of brandy used in fortification.

Apple pomace is handled in similar manner by drying and grinding as described for grape pomace. It is of lower protein and fat content than grape pomace but is rich in carbohydrates. Therefore, it is a good supplement to the latter.

Olive pomace contains a large proportion of seeds, which must be removed or finely ground before the pomace may be used as a stock food. The seeds may be removed by drying the pomace, breaking it into individual seeds and particles of pulp, and screening in a blast of air. The seeds are valuable for fuel, and the pulp and skins may be used for stock food. The pulp is rich in oil.

Raisin Seeds.—In the packing of Muscat raisins in California the waste seeds constitute about 8 to 12 per cent of the original weight of the raisins, or a total of about 5,000 tons annually. Adhering to the seeds is a considerable amount of pulp and syrup, which contains sugar equal to about 20 per cent of the weight of the seeds, and the seeds contain oil and tannin, both valuable constituents.

The freshly separated seeds soon develop fermentation and become moldy, if allowed to stand. It is therefore necessary to treat them at once if the sugar is to be recovered or utilized.

The seeds may be washed with warm water to dissolve the sugar from the adhering pulp and syrup. The solution, which contains sugar and other grape solids, can then be filtered and concentrated in a vacuum pan to a syrup of the desired density for table use, baking, etc. However, at present it is used for production of brandy.

The sugary extract from the seeds can be fermented with yeast and distilled to obtain ethyl alcohol or brandy. This is being done at present in a by-products factory in Fresno, Calif., and the resulting brandy is used by various wineries in fortifying sweet wines. A simplified procedure consists in fermenting a mixture of water and unwashed seeds, draining off the fermented liquid for distilling and drying the residual seeds.

The alcoholic distillate may be diluted to about 10 per cent alcohol and acetified in vinegar generators to give a distilled vinegar of good quality suitable for preservation of pickles or for table use.

The washed seeds are dried in a rotary drier in a blast of hot air and crushed and pressed in hydraulic presses, although expellers could be used to good advantage. The yield of oil, its chemical composition, and general qualities are very similar to those noted previously for oil from grape seeds obtained from pomace from grape-juice factories and wineries. At present the oil is sold for industrial purposes, *i.e.*, soap making, paints, etc., and is also used, after partial hydrogenation, for coating seeded raisins to prevent stickiness.

When properly refined, raisin-seed oil can be made into a very palatable table oil.

Some of the press cake is sold for stock food but is very high in crude fiber and should be mixed with other feeds before use.

Raisin Stems.—Waste stems from the stemming of raisins in California have been utilized for fertilizer, their principal fertilizing ingredient being potassium. They are dried, ground, and applied to the soil with or without the addition of other substances. There is a total of approximately 7,800 tons of stems available in California annually.

The stems may be utilized for recovery of cream of tartar and tannin or may be ground for use in mixed stock foods.

Utilization of Surplus and Cull Fruits.—The utilization of surplus and cull fruits presents a much more important and difficult problem than the utilization of waste pits, pomace, seeds, and other waste products from factory operations. It is estimated that the surplus and cull fresh peaches not utilized in California at present amounts to about 100,000 tons annually. The quantity of cull apples at present not utilized is very large; no estimate is available. Large tonnages of surplus and cull dried prunes, fresh Bartlett pears, and plums are not utilized.

Such fruit can be utilized in preparing fruit jams, dried products, juices, wines, brandies, vinegar, denatured alcohol, stock foods, etc. Most of these products are discussed in other chapters, to which the reader is referred. The other products will be discussed briefly.

At present so-called "power alcohol," ethyl alcohol, for admixture with gasoline for use in gasoline motors is in the public eye. On first thought this outlet appears attractive; but the production of alcohol from surplus fruits for this purpose will not bear analysis. For example, gasoline costs wholesale f.o.b. refinery about 5 cents a gallon; denatured alcohol from the cheapest raw material (molasses) costs not less than 25 cents a gallon. It would cost at least 35 cents a gallon if made from waste fruit, if the operator were to recover his operating costs. Alcohol can be made very cheaply from the ethylene from cracked petroleum. Therefore, if gasoline producers were forced by law to add alcohol to gasoline, they would probably make it from petroleum. Gasoline-alcohol blends require special carburetion and engine adjustment. Further-

more, in moist weather they may absorb water rapidly and separate into a layer of water-alcohol and one of gasoline. A ton of cull peaches would yield at most 10 gal. of absolute alcohol (only absolute, water-free alcohol can be used in gasoline). This would be worth wholesale, at a price competitive with gasoline, 5 cents a gallon, only 50 cents; or at the industrial alcohol price, 25 cents a gallon, \$2.50. The cost of picking and delivery of the fruit is not less than \$2.00 a ton and of manufacture not less than 15 cents a gallon of alcohol or \$1.50 a ton of fruit. On either basis the operator would lose money.

For brandy production the possibilities are more attractive. A ton of peaches or pears would yield about 20 gal. of brandy of 100 proof (50 per cent alcohol). After aging and payment of the federal tax of \$2 per 100-proof gallon, it is likely the brandy could be sold at a profit if properly aged and introduced by adequate advertising. The procedure of manufacture consists in crushing, fermenting with pure yeast in the presence of about 100 p.p.m. of sulfur dioxide, and distilling in a pot still (batch, or discontinuous still); or in grinding the fruit to a fine purée in a hammer mill, fermenting as above, and distilling in a continuous still as is done in making whisky or wine brandy. In any case construction and operation of a fruit brandy plant requires that the operator secure the necessary state and federal permits and conform to the many stringent federal regulations. Details may be secured from the Alcohol Tax Unit of the Bureau of Internal Revenue and from the Federal Alcohol Control Administration, both of Washington, D. C.

Cull and surplus apples, grapes, oranges, and other juicy fruits suitable for brandy making are crushed, fermented, and pressed as in making red grape wine. The pomace may be leached with water to recover residual alcohol. Pure yeast and sulfur dioxide should be used to secure efficient fermentation.

Cull dried fruits are mixed with about four volumes of water, fermented with pure yeast in the presence of sulfur dioxide, drained, and extracted with water. The first drained liquid is distilled; the water extract is added to the next lot of dried fruit. The residual fruit is dumped, although it could be pressed, dried, and ground for stock food. Dried fruits after fermentation could be ground to a fine purée in a hammer mill and distilled in a continuous still.

Fruit wines are described elsewhere (see Chap. XXX).

Fruits in dried form can be used successfully in breakfast cereals by combining them in a thick dough made of whole wheat flour or corn meal, flaking, cooking, and drying. Prune cereal made in this manner is palatable and has a mild laxative action.

Fruits can be used in many bakery products to a greater extent than at present. This is particularly true of dried fruits. Bread containing

20 to 30 per cent of chopped dried prune meat is an example of such products.

Fruits can be used very successfully to a much greater extent than at present in carbonated, low-priced fruit beverages. Dried prunes yield a very palatable, mildly laxative canned or bottled juice that should have great commercial possibilities (see Chap. XV for details of producing carbonated beverages, canned prune juice, and other fruit beverages).

All such specialties, however, require for commercial success that the project be generously financed for a period of several years, because successful introduction of new food products requires much costly advertising and sales promotion. Failure to recognize this basic fact has been the cause of many failures in such ventures.

The utilization of cull citrus fruits is presented in Chap. XXVIII.

Recently a national organization, supplemented by similar state organizations and known as the National Farm Chemurgic Council, has come into existence. Its national headquarters is in Detroit, Mich. Its purpose is to promote the utilization of farm wastes and farm surpluses for nonfood purposes and, as well, the production of new crops for such purposes. Examples of such projects are the growing of slash pine in the South for use in paper pulp, utilization of soybeans for plastics and soapmaking, greater production of flax for fiber and paint oil, pressed fuel "logs" made of waste wheat straw, and the conversion of carbohydrate wastes into butyl alcohol and acetone by suitable bacterial fermentation and distillation. Still more recently the Federal government has appropriated funds for four regional by-products laboratories in the United States for research on utilization of surplus crops including surplus fruits and vegetables.

Waste Juices from Canning.—In the pitting of cherries a large amount of juice accumulates and is generally not utilized. Rabak (1916) estimates the juice so obtained at 70 gal. per ton of fresh cherries. It could be collected, heated, filtered, and added to the syrups used in canning cherries.

The juice is also suitable for the manufacture of vinegar or denatured alcohol or, when partially neutralized with calcium carbonate and concentrated *in vacuo*, yields a palatable table syrup. It may also be combined with pectin and sugar to give jelly or canned as a juice for beverage use.

Waste Syrup from Canning.—It is estimated that the waste of syrup from sealing and syruping machines in an eight-line fruit cannery involves a loss of 400 to 700 lb. of sugar per day. In the past this syrup has not been recovered in most canneries. A system and a machine have been developed for the recovery and refining of such waste syrup. The syrup is gathered in drains beneath the syruping and sealing machines

and is pumped to the refining equipment, where it is mixed and heated with decolorizing carbon and infusorial earth and is filtered in a small filter press. The syrup is freed of oil, color, and objectionable flavor by the refining process and can be used in canning.

Olive By-products.—In California most of the small olives—fruit damaged in pickling, frosted, and other cull olives—are utilized for oil (see Chap. XXVI).

Some of the small olives are pickled and pulped in a tomato pulper equipped with a heavy specially constructed screen. The resulting "purée" is mixed with salt and spices and is then canned and sterilized. It is known as "olive mince" or "olive relish" and is used for sandwich fillings, sauces, and as a flavoring in cooking. Chopped pimentos, green peppers, and horse-radish give an excellent blend with olives. This product has been replaced largely by canned, unflavored minced olives prepared as follows. Pickled, small olives are pitted by machinery, chopped, and canned as a mince or relish. The canned product requires a process of 240°F. for 90 minutes.

The pomace from olive oil manufacture is utilized in California for fuel but in Europe is extracted with volatile solvents for recovery of the residual oil (see Chap. XXVI).

UTILIZATION OF VEGETABLE WASTE

In the canning of vegetables and the manufacture of tomato products a considerable proportion of the vegetables is discarded as waste or is often only partially utilized. Studies by Rabak and others have proved that waste tomato seeds and skins in particular are worthy of study for the preparation of by-products.

By-products from Tomato Seeds and Skins.—Rabak (1917) estimated the average quantity of waste peels and seeds from tomato products factories at 16,000 tons on a wet basis or, approximately, 3,000 tons of dry material, of which about 1,500 tons are seeds and 1,500 tons dry skins. At present the quantity is considerably greater.

Drying Waste and Separating Seeds.—The seeds must be separated from the skins before the oil is extracted. In Italy, according to Rabak, (1917) the waste is passed through a continuous press to remove as much of the excess water as possible, and it is then dried in a continuous drier by a blast of air heated by steam coils. In a large California plant the waste skins and seeds are pressed in a continuous press, dried in a rotary drum drier, ground in a hammer mill, and sold for use as stock food.

The seeds may be separated from the dried material by screening and fanning.

Extraction of the Oil.—The oil is usually recovered in Europe by pressure in an expeller, *i.e.*, continuous oil press, or by solvent extraction.

A maximum of about 20 per cent of oil is obtainable by this means. The press cake may be combined with the dry peels for stock food.

Refining the Oil.—The objectionable odor of the raw oil may be removed by treatment with a current of steam, the excess acid may be neutralized with sodium carbonate or dilute sodium hydroxide, and heating with fuller's earth and filtration will remove excess color. The refined oil is suitable for food.

Centralized Plants Necessary.—It is not feasible for individual canneries and tomato products factories to undertake the manufacture of tomato by-products other than stock food. It would be possible, however, to dry the waste at the various plants and ship it to a centrally located plant to be converted into oil and stock food.

Asparagus Waste.—In the cutting of asparagus stalks for canning approximately 50 per cent is wasted. Some of the material is shredded, ground, or cut in short segments and canned for soup stock, but most of the waste is discarded. It contains 93 to 97 per cent moisture and is of little value for stock food. It has been found that a palatable concentrated soup stock can be obtained by evaporating *in vacuo* the juice expressed from the boiled stalks.

Waste from Pea and Corn Canning.—The vines and pods from pea canning and the husks from corn canneries are seldom allowed to go to waste but are used as stock food, either in the fresh state, dried and cured as hay or fodder, or as ensilage. Pea vines are improved for siloing purposes if mixed with corn silage, for the reason that they are apt to undergo undesirable putrefactive changes in the silo unless mixed with other materials low in protein and rich in carbohydrates.

Green corn cobs from canneries are rich in carbohydrates and may be used in the silo if finely shredded.

Spinach crowns and trimmings are succulent and low in food value but can be utilized profitably for feeding purposes if not allowed to become moldy or otherwise decomposed.

Vegetable Oils.—The manufacture of by-products from cottonseed, soybeans, peanuts, sesame seed, corn germs, etc., although extremely important, does not logically fall within the scope of this book, because they are field crop by-products rather than fruit or vegetable by-products. The subject of fixed vegetable oils is so important and the published literature is so extensive that a separate book would be required to do it justice. See references at end of this chapter.

DISPOSAL OF CANNERY AND OTHER WASTES

In addition to utilizing various fruit and vegetable wastes there is the problem of disposal of wastes from canneries, wineries, olive oil factories, etc., in such manner that they do not unduly pollute streams or become a

public nuisance. A great deal of attention has been given to this problem in Wisconsin, Ohio, and New York by the respective State Boards of Health.

In brief the findings were as follows (for details see the references at the end of this chapter):

The treatment of canning wastes (particularly corn and pea wastes) by mechanically operated, fine-mesh, rotary screens to remove solid materials, followed by passage of the liquid wastes through trickling filters, such as used in many city sewage-disposal plants, gives satisfactory disposal. These treatments require relatively little labor for operation, although the cost of construction may be high in comparison with that of chemical precipitation plants.

The screening of the wastes followed by coagulation with ferrous sulfate and lime and sedimentation in suitable tanks provides another satisfactory method of treatment. The cost of operation is rather high because of the necessity of employing a full-time operator and of drying and disposing of large amounts of sludge. The sludge has some fertilizing value.

Chlorination of the final effluent is effective as a final treatment.

The extent of treatment, naturally, depends upon the dilution of the final effluent, *i.e.*, upon the volume of water passing through the stream into which the final effluent flows, or upon the dilution of the waste at the plant. Where very high dilution is possible simple screening is all that is required. If somewhat less dilution is available, then screening and trickle filtration at the rapid rate of 2,000,000 gal. per acre per day may suffice. At lower dilution it may be necessary to screen and to trickle filter at the slow rate of 500,000 gal. per acre per day. At still lower dilution, *e.g.*, about 5 to 1 it will probably be necessary to screen, trickle filter at 500,000 gal. per acre per day, and chlorinate the final effluent.

The wastes from the canning of peas, tomatoes, green beans, various fruits, and kidney beans has been found to contain 5 to 15 times the organic matter of domestic sewage. About 25 gal. of waste is produced for each case of peas and about 90 gal. for each case of tomatoes. A two-line cannery producing 4,000 cases of canned product a day produces wastes equivalent to the sewage from 10,000 people. It is evident, therefore, that cannery wastes can cause serious pollution.

It is possible to separate the objectionable wastes from the harmless wastes such as condenser water, cooling water, and rain water from the roof.

The wastes from pea, corn, Lima bean, and succotash canning were found to be highly putrescible as evidenced by the high B.O.D. value (biological oxygen demand). Good coagulation was attained by addition of 15 to 20 grains of aluminum sulfate and 5 to 8 grains of soda ash

(Na_2CO_3) per gallon. About 18 tons of sludge was produced per million gallons. The effluent was still putrescible.

In the Ohio experiments trickle filtration through stone or lath filters under aerobic conditions at the rate of 2,000,000 gal. per acre per day, *i.e.*, 250,000 gal. per acre-foot, gave good results with the screened, but not chemically treated, liquid wastes. Clogging and sludge formation did not occur. Sand filters also gave satisfactory effluents, although at a lower rate per acre per day.

In California the disposal of waste still liquids from wine brandy stills is a serious problem. From experiments conducted by H. E. Jacob of this University, it appears that it is feasible to run the waste liquid into a plot of idle land for a few days, let it soak into the ground, plow or cultivate the plot, and let it lie idle for a few days while other similar plots are receiving the waste. Then the first plot may be used again and the cycle repeated until the soil becomes clogged. For a considerable period the soil remains toxic to plants. Evidently biological oxidation occurs in the cultivated soil and thus removes much of the organic matter.

Tartrates may be recovered by treatment with lime. The resulting effluent is then more readily treated by trickle filtration, especially if diluted with several volumes of water. Still-waste liquids ("still slops") are highly putrescible and, if in sufficient concentration, kill fish in streams and, if applied in too great quantity to vineyard soils, kill vines.

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CHAPTER XXVIII

CITRUS BY-PRODUCTS

The utilization of the fruit unsuitable for fresh shipment has become a serious problem in the citrus fruit regions of the United States. However, rapid progress is being made in the development, on a commercial scale, of processes of converting this waste fruit into valuable by-products.

The manufacture of lemon by-products in Italy and Sicily is an established industry of long standing, but the methods in use in Italy are for the most part not adaptable to American conditions, because hand labor, upon which the Italian processes depend, is too costly here. The development in the United States has therefore been in the nature of devising mechanical means of accomplishing what is done in Italy by hand methods.

MANUFACTURE OF CITRIC ACID IN CALIFORNIA

Citric acid is used in very large quantities in the preparation of carbonated beverages and in the dyeing of fabrics. The United States, according to a report of the Citrus Protective League of California, at one time imported about 75,000 lb. of citric acid and about 6,000,000 lb. of citrate of lime per year. The citrate was converted into citric acid in factories located in various cities on or near the Atlantic coast. At present California produces 500,000 to 3,000,000 lb. of citric acid, or acid and citrate, annually. Much citric acid is now produced by the action of Aspergillus niger mold on sugars.

Raw Material.—Cull lemons from the fresh-fruit packing houses form the usual raw material. Most of this fruit is sound and practically free from mold or decay.

The fruit often is shipped to the factory in open gondola cars holding 20 tons of fruit each. Smaller shipments are received by truck or in sacks or boxes by freight. According to Wilson (1921) 13,000 to 20,000 tons annually must be utilized by the California Fruit Growers' Exchange in order to dispose of surplus production and culls. Lemon juice usually contains from 4.5 to 6 per cent citric acid.

Sorting.—By the process in use until 1921 the fruit was first sorted on a broad conveyer. That free from rot and serious blemishes was sent to the peeling machines to be peeled for oil recovery before being crushed for citric acid manufacture. At present most of the fruit is not sorted before crushing and very little is peeled before crushing.

Peeling.—At one time much of the fruit was peeled or grated in mechanical peelers similar in appearance and operation to the mechanical peelers described in Chap. XXII for the peeling of potatoes and other vegetables.

The peels so obtained were pressed to obtain oil of cold press quality and the press cake was distilled to recover the essential oil of the lemons.

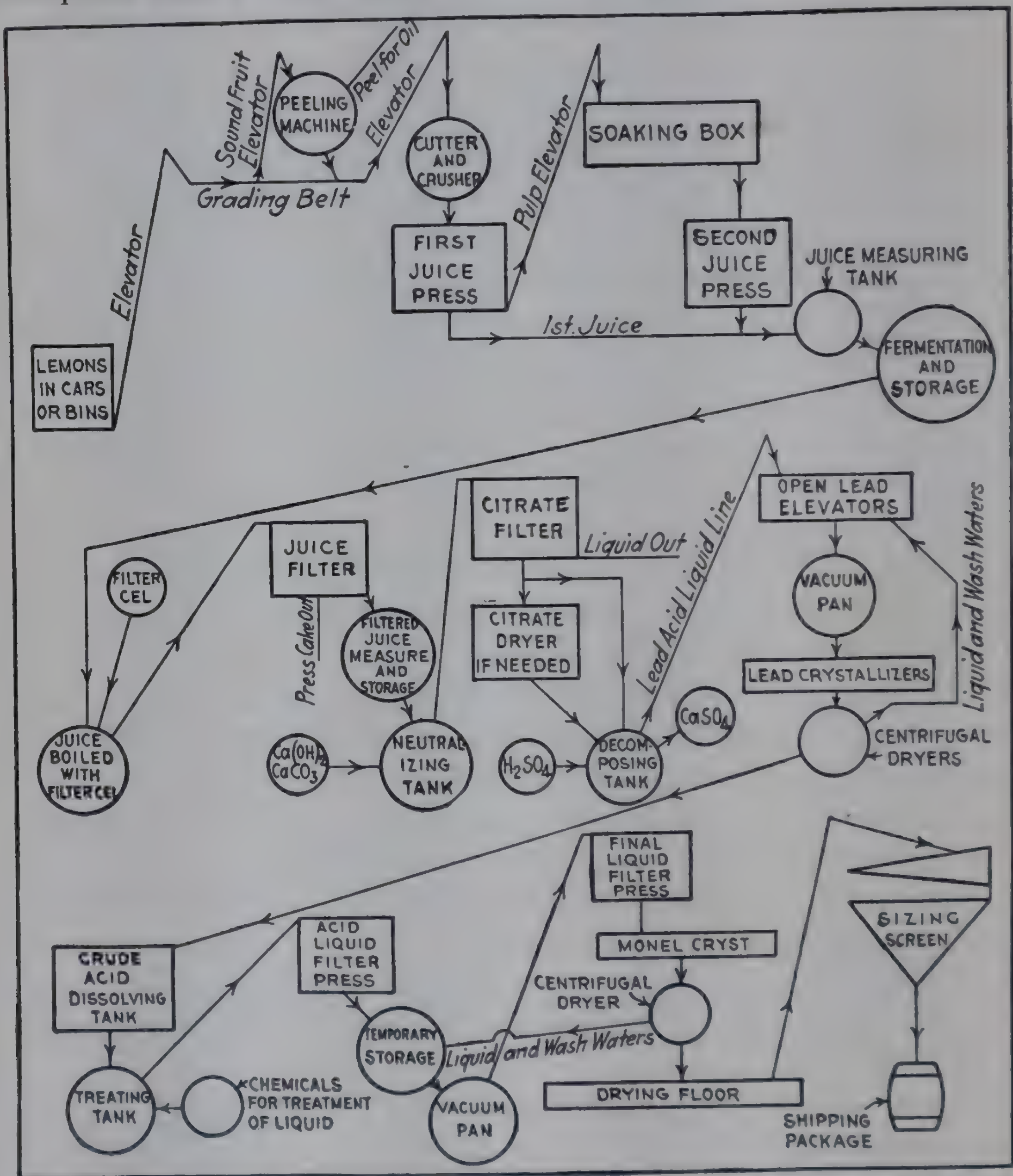

FIG. 99.—Flow sheet for the manufacture of citric acid. (*After C. P. Wilson, Exchange By-Products Co., Research Laboratory.*)

At present most of the fruit is pressed without peeling, and the oil is recovered by other means.

Extraction of the Juice.—The fruit first passes by means of an elevator to a slicer fitted with revolving knives, which tear the fruit coarsely and facilitate pressing, and through wooden rollers which bruise the fruit thoroughly, pressing out some of the juice.

The crushed fruit is pressed in a continuous screw press, which expels the juice mixed with considerable pulp. The pressed material is elevated to a soaking box where it is wet with water and is pressed a second time to recover the acid remaining in the press cake. The press cake from the second pressing is again soaked with water and pressed a third time. The third pressing juice is used for maceration of the pulp from the first pressing, while the second press juice is combined with that from the first pressing in the measuring tank. The combined liquids contain about 4 per cent of citric acid.

Experiments have been made upon extracting the juice by means of large fluted rolls without previously cutting the fruit. The rolls extract some of the oil which may be recovered by distillation or centrifuging.

Fermentation of the Juice.—The freshly pressed juice is very difficult to filter on account of the presence of gums and pectin, but it has been found that fermentation of the juice destroys much of the "sliminess" and renders filtration rapid. The juice is stored in large tanks holding about 57,000 liters each and is permitted to undergo spontaneous alcoholic fermentation. Fermentation requires about 5 days in warm weather and about 10 days in cold weather. Very little citric acid is lost during fermentation. Prolonged standing of the juice results in the growth of film yeasts ("wine flowers") with resulting rapid loss in acid. The juice must be handled promptly after fermentation is complete.

Boiling.—The fermented juice is mixed with a small amount of infusorial earth in wooden tanks heated by copper steam coils. During boiling of the mixture, samples are withdrawn and allowed to settle a few minutes. If settling is not rapid, more of the earth is added until the desired result is obtained.

Filtration.—The hot liquor is filtered by means of a copper-lined Sweetland filter press and by plate and frame filter presses of large size and capacity.

The filtrate from the filter press is brilliantly clear, is of light amber color, and contains about 4 per cent of citric acid.

Precipitation of Calcium Citrate.—The filtered juice is placed in wooden tanks fitted with steam coils and mechanical agitators. Based on a titration of the total acid of the juice, enough hydrated lime is added to neutralize approximately 90 per cent of the total acidity of the juice estimated as citric acid. The remaining 10 per cent of the acid is neutralized with calcium carbonate, and an excess of carbonate is added. If hydrated lime is used to neutralize the acidity completely, it precipitates pectic substances and gums, darkens the color, renders decolorization of the liquids later in the process very difficult, and causes the final crystals to be dark colored.

The mixture is agitated and boiled until the reaction is complete. The boiling hot solution is pumped to the filters.

Filtration to Recover Calcium Citrate.—Neutralization of the juice with calcium hydroxide and carbonate results in the formation of insoluble calcium citrate, which is obtained as a finely divided white precipitate. Calcium citrate is more insoluble at high than at low temperatures, and it is therefore necessary to filter the liquor at as high a temperature as possible.

Continuous, rotary-drum type suction filters are used in filtering the citrate liquors to recover the citrate. The solid calcium citrate accumulates on the surface of the revolving drum and is scraped from the drum into a conveyer.

The wet calcium citrate is conveyed to the tanks for decomposition with sulfuric acid, although some of the citrate is dried and stored for later use in making the acid. Dry citrate should contain about 67 to 68 per cent citric acid, *i.e.*, if the citrate is decomposed with a mineral acid, 67 to 68 per cent by weight of citric acid should be liberated.

Decomposition of the Citrate.—The filter cake is mixed with wash water from a previous lot of calcium sulfate crystals to form a thin paste. Sulfuric acid (66° Baumé) is mixed with the citrate and the mixture agitated until the reaction is complete. If the acidity and the volume of the original juice are known, it is possible to calculate the approximate amount of sulfuric acid required for liberation of the citric acid. It is desired that there be present after the reaction is complete not more than 0.2 per cent of free sulfuric acid.

The end point is determined by testing the liquor with methyl violet indicator paper, the end point being indicated by change of the violet color to greenish blue.

A slight excess of sulfuric acid aids in crystallization of the acid, but a large excess will cause darkening of the acid liquors by caramelization and will cause the finished citric acid crystals to be dark in color.

Filtration to Remove Gypsum.—In the decomposing tanks calcium sulfate (gypsum) is formed as an insoluble precipitate, and the citric acid goes into solution. The acid liquor has a density of 5 to 6° Baumé and an acid content of 12 to 15 per cent citric acid.

The calcium sulfate precipitate is removed by means of a continuous, rotary-drum type suction filter and may be dried and used by the orchardists as a fertilizer.

The filtered liquor is brilliantly clear and of light-amber color.

Concentration of Acid Liquor.—The filtered acid liquid is placed in shallow lead-lined tanks heated by coils to near the boiling point. Air is passed through the liquid continuously and causes fairly rapid evaporation of the excess water, until the liquid is concentrated to about 25°

Baumé. The calcium precipitate which forms is filtered off. Concentration of the first liquor is completed in lead-lined vacuum pans holding about 7,000 liters each; the final density of the hot liquid (at 50°C.) is 37 to 39° Baumé.

First Crop of Crystals.—The concentrated solution from the vacuum pan is placed in lead- or monel-metal-lined crystallizing vats and allowed to stand from 3 to 5 days, permitting the formation of large crystals of citric acid on the walls and floor of the vats.

Centrifuging.—The crystals are placed in a centrifuge basket and washed with sprays of cold water to remove adhering mother liquor. The mother liquor is of dark color but yields a second crop of crystals by concentration and crystallizing. When the mother liquor no longer yields desirable crystals, it is sent to the neutralizing tanks, is diluted with water, and treated as fresh juice so that none of the acid will be discarded.

Dissolving Crude Crystals and Removal of Metallic Salts.—The centrifuged crystals are dissolved in water by placing them in a lead basket at the surface of a tank of water.

The impurities to be removed are: (1) organic color; (2) lead salts; (3) copper, tin, and antimony salts; (4) iron and nickel salts; (5) sulfuric acid; and (6) calcium sulfate.

The organic coloring matter is removed by heating the liquor with 1 to 2 per cent of its weight of high-quality decolorizing carbon. The liquid is filter pressed to remove the decolorizing carbon.

Sulfuric acid, if present in excess, is precipitated by adding to the liquor in the vacuum pan a calculated amount of milk of lime (hydrated lime) and the precipitate removed by filtration before decolorization with carbon.

Hydrogen sulfide water is added to the liquor to precipitate lead, copper, tin, and antimony salts, which may have been dissolved by the acid solutions during their passage through pipes, by heating in lead tanks, or by contact with metal at other points in the process.

When iron first dissolves in the juice, it is in the ferrous state. Treatment with air in the open evaporators oxidizes it to the ferric state, making it possible to precipitate it as a ferrocyanide. The amount of calcium ferrocyanide found necessary by laboratory test to precipitate the iron and nickel salts is added to the acid solution. If left in the solution, iron and nickel salts would discolor the final acid crystals and render them unsalable as U. S. Pharmacopoeia citric acid.

Enough ferrocyanide is added to precipitate about 90 to 95 per cent of the iron and nickel salts. An excess of the ferrocyanide would pass into the monel metal vacuum pan and there react with the nickel to give nickel ferrocyanide, which would discolor the final crystals. The small

traces of iron and nickel left in the liquor do not affect the color of the citric acid crystals.

These reagents are added before the filter char is added. This is next added as noted elsewhere, and the mixture is filtered through a cloth and frame filter press.

Concentration in Vacuo.—The filtered acid solution is concentrated in a monel metal, stainless-steel, or glass-lined vacuum pan to 36 to 37° Baumé (at 50°C.).

Filtration to Remove Calcium Sulfate.—The concentrated liquor is again filter pressed to remove calcium sulfate precipitated during concentration and small amounts of other insoluble metallic salts that may be present.

Final Crystallization.—The filtered, concentrated liquor is placed in glass-lined or monel-metal-lined vats for final crystallization. During crystallization the crystals are stirred occasionally by paddles by hand or continuously by mechanical stirrers, to prevent the formation of large crystals. Crystallization generally requires 3 to 5 days.

Centrifuging Final Crystals.—The crystals are washed in a basket centrifugal with a small amount of water and the washings recovered and mixed with other acid liquors.

Drying Crystals.—The crystals are usually dried in the open air on the floor in a layer about 4 to 5 in. in depth, but in rainy weather it is necessary to dry them by artificial heat in a vacuum-shelf type of drier.

The crystals are packed in paper-lined barrels or boxes and in order to conform to the U. S. Pharmacopoeia standards in purity must contain less than 0.5 per cent ash and be water-white in color. Powdered acid may be made by grinding and sieving the crystals.

CALCIUM CITRATE AND LEMON OIL MANUFACTURE IN ITALY

Considerable citric acid is made in Italy, although a larger amount of the intermediate product, calcium citrate (usually known in the trade as citrate of lime), is produced and exported to Germany, England, and, to less extent, the United States to be converted into citric acid. Oil of lemon is also produced on a large scale for export. Other Italian lemon by-products are salted peel and concentrated lemon juice.

The preparation of oil and citrate is conducted under one roof and from the same fruit—hence the necessity of considering the two processes together.

According to Powell and Chace, Italy at one time exported approximately 17,000,000 lb. of citrate of lime. He also states that the normal amount of lemon oil exported from Italy was approximately 1,000,000 lb. annually.

Extracting Oil.—The oil is usually extracted by hand, two methods of preparing the rind being used. In the "three-piece" method the rind is removed in three strips lengthwise of the lemon. In the two-piece method the lemon is cut in half, and the flesh is scooped from the fruit by means of a sharp spoon. The pulp from either method of peeling is used for the preparation of juice for citrate, and the rind is used for oil.

The peels are pressed by hand over a bowl; the juice and oil are caught by sponges and are periodically pressed into the bowl. The oil is decanted from the juice by tilting the bowl forward and blowing the breath on the surface of the oil.

The oil is allowed to settle for 24 hr. and is then filtered through paper and stored in large copper cans, which exclude light and thus minimize deterioration.

The residue from the bowl contains considerable oil, which is recovered by distillation in crude stills. Distilled oil is of poor quality and becomes "terpeney" (of turpentine-like odor) rapidly but is often used in adulterating the hand-pressed oil.

In Calabria, Chace states that lemon oil and oil from the rinds of oranges are obtained by use of a machine in which the whole fruit is placed between two disks which have rough, abrasive surfaces and one of which revolves. The outer portion of the rind is grated from the fruit, the grated fruit wiped with a sponge, and the juice and oil so collected expressed from the sponge. The oil is of excellent flavor, is darker in color than the hand-pressed oil, and is used largely for blending with the latter to intensify its color. In 1924 the present writer saw in use in Sicily machines of the ecuelling type. The whole fruit passed over hundreds of needles which punctured the oil cells and liberated the oil. The oil was washed off the fruit by a fine spray of water and was recovered by centrifuging. In Messina and vicinity in Sicily are located several modern plants for the recovery and purification of lemon oil by mechanical means. Consequently, the sponge process is declining in importance.

Citrate of Lime.—The pulp or peeled fruit from the oil room is crushed by wooden rollers operated either by mechanical means or by hand power. The crushed fruit is placed in heavy, closely woven, straw mats, and these are placed one above the other and subjected to heavy pressure in a large screw hand press, the bags acting as filters as well as press cloths.

The juice is placed in a tank in which it is heated nearly to boiling by a steam coil or by direct heat, and milk of lime is added until the liquid is neutral to litmus paper. After heating for several hours, the hot liquid is placed in a tank fitted with a filtering cloth on which the citrate collects as a voluminous white powder. After the liquor has drained off, the citrate is shoveled into small bags and pressed to remove excess liquid.

It is removed from the bags to iron pans, which are stacked on racks in a room heated with a large charcoal burner, and there dried.

The dry citrate is broken into small pieces and packed in hogsheads holding about 675 lb. each. Each lot is sampled, analyzed, and is sold to brokerage houses. The citrate usually contains more than 60 per cent of citric acid.

Citric Acid.—The citrate is converted into citric acid in Germany, England, and the United States by methods similar to those described earlier in this chapter. There is at Palermo, Sicily, a very large, modern citric acid factory in which citric acid is produced for both export and domestic purposes.

Yields.—Chace states that 100,000 lemons (10 to 12 tons) yield 100 lb. of oil and 675 lb. of citrate of lime. This corresponds to 8½ to 10 lb. of oil and about 56 to 67 lb. of citrate per ton, or approximately 35 to 43 lb. of citric acid per ton.

ORANGE AND LEMON OILS IN CALIFORNIA

Four methods have been used in California for the recovery of the essential oils from cull oranges and lemons. These processes are: (1) by pressure and centrifugal separation, (2) by steam distillation, (3) by removing the outer portions of the rinds by grating or "shaving" and pressing of the resulting rind, and (4) by extraction with petroleum ether.

By Pressure and Centrifugal Separation.—The whole fruit is crushed and pressed in a continuous pressing device, the oil and juice separated by means of a special high-speed centrifugal separator and the crude oil filtered through paper. The yield is relatively low, seldom in excess of 6 lb. per ton.

The oil is usually lower in citral content than the imported oil because the juice dissolves an appreciable proportion of this ingredient.

Waste orange juice may be used for canning, etc., or preparation of concentrate or syrup for soda fountain and bottlers' use. The lemon juice is used for citric acid manufacture.

By Steam Distillation.—The ground press cake from whole oranges or lemons, the gratings from mechanically peeled oranges or lemons, or the pressed whole fruit may be ground and distilled in a current of steam to recover oil not removed by other means. The resulting oil is water-white and much inferior to the cold-pressed oil in color and flavor. It is also very unstable and rapidly deteriorates unless held in cold storage.

Steam distillation *in vacuo* yields an oil superior in flavor and keeping quality to that obtained by steam distillation at atmospheric pressure.

By Peeling and Pressing.—Lemons and oranges may be peeled in a modified vegetable peeling machine, such as is used in grating the peel off potatoes, which removes the outer portion of the rinds in the form of

gratings which may be pressed to obtain an oil of good quality. The press cake may be distilled in a current of steam to recover the remainder of the oil, which will be of poor flavor and poor keeping quality and should not be mixed with the cold-pressed oil. A new machine now in use flattens the halved whole fruit between large horizontal rollers, thus expressing the juice. A safety-razor-like attachment "shaves" off the oil-bearing layer from the flattened peel and delivers it to a conveying belt. The oil can then be recovered by pressing. The press cake may be steam distilled.

Recovery of Oil by Use of Solvents.—At one time orange and lemon oils were prepared in Redlands, Calif., by the following method: The outer portion of the peels was first removed by hand peeling and the oil recovered by treatment of the peels with a volatile solvent. It was found impossible to remove the solvent completely from the oil and the process was therefore abandoned.

OTHER CITRUS BY-PRODUCTS

Numerous other citrus products and by-products are produced commercially in the United States and in European countries.

Marmalade.—England imports from Spain large quantities of bitter, so-called Seville oranges, which are utilized in the preparation of marmalade, and in California and Florida marmalade is produced commercially from cull citrus fruits (see Chap. XVIII).

Marmalade Juice.—It has been demonstrated by experiments at the University of California that the juice expressed from cooked citrus fruits and combined with the sliced peels can be sterilized in cans and shipped to marmalade factories or sold to housewives for the preparation of marmalade. It is believed that this product has commercial possibilities (see Chap. XVII).

Citrus Fruit Juices and Syrups.—Large quantities of cull oranges are used for the preparation of juice which is sold direct to the consumer immediately after it is produced. Large amounts are also canned, as described in Chap. XV, and appreciable quantities of citrus fruits are also used for the preparation of concentrates and syrups (see Chaps. XV and XVI).

Orange Vinegar.—Orange juice normally contains from 12 to 16 per cent total solids, of which about 9 to 13 per cent is sugar. If the juice is carefully fermented with selected yeast, it is possible to obtain a fermented juice containing 4.5 to 6 per cent alcohol by volume, which will yield vinegar above the legal limit of 4 per cent acetic acid (see Chap. XXIV).

Dehydrated Citrus Products.—Orange and lemon peels are dried in halves to a limited extent for the use of extract manufacturers and bakers

and for use in flavoring medicinal preparations. The waste peels from juice factories are now dehydrated in large direct-heated rotary driers, ground, and sold to dairy operators and others for use as stock food.

Recently the sliced fruit has been dehydrated until very brittle and has then been ground to a powder. The powder is used as a flavoring material in cakes, pies, cookies, etc., and for flavoring plug tobacco.

Dried Juices.—Lemon and orange juices may be dried to powders in the same manner as milk, egg white, etc., if sufficient refined corn sugar or milk sugar is added before drying to prevent stickiness and lumping (see Chap. XVI).

Pectin.—Lemon waste from the manufacture of citric acid is very rich in pectin. C. P. Wilson and his associates in the Research Laboratory of the California Fruit Growers' Exchange have developed a process of preparing a powdered lemon pectin commercially (see Chap. XVII). It is also made by other processes as described in Chap. XVII.

Candied Peel.—Candied citron (a citrus product) is a well-known article of commerce. The citron peels are shipped in brine to the United States from Italy and other Mediterranean countries for preparation of candied peel. The bitterness is extracted by boiling in repeated changes of water, and the peel is candied by methods described in Chap. XVIII.

Orange and lemon peels are also imported from Italy in brine and converted into candied peel.

Paste for Bakers' and Confectioners' Use.—In California a paste was at one time prepared from oranges by grinding the whole fruit, adding sugar and concentrating in a glass-lined vacuum pan to a heavy consistency, giving an excellent product for flavoring cakes, pies, and other bakery products and for use in candies. Another product for bakers' use consists of the ground whole fruit and an equal weight of sugar, which mixture is cooked and sterilized in cans.

Confections.—In addition to the candied peel it is possible to prepare candy from citrus fruits, a very satisfactory candy center being made by combining lemon pectin and ground, whole, cooked orange pulp with sugar and concentrating to the jellying point. The stiffly jellied mixture can be molded in starch or cut in cubes and dipped in chocolate or coated with fondant.

Canned Citrus Fruits.—Grapefruit pulp is now canned in Puerto Rico and Florida to be served as a breakfast dish (see Chap. XI). Broken segments of grapefruit blend well with other fruits in canned fruit cocktails, salads, etc.

Oranges were at one time canned in California after peeling by hand and slicing crosswise in thin sections. These were canned in a syrup of about 40° Balling and were pasteurized in the can. The canned product

was used by sailing vessels, but a disagreeable "stale" flavor developed in the can on storage.

Wines, Brandies, Cordials.—Dry and fortified wines may be made from oranges and grapefruit as described in Chap. XXX. Brandies can also be made; likewise cordials, the latter by adding brandy and sugar to the wines.

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CHAPTER XXIX

PACKING CASES[1]

In recent years a great deal of study has been given by governmental and commercial agencies to the design, construction, and behavior of all types of containers for canned and glassed foods for the purpose of improving the containers and of conserving timber. Both objects have been attained to a remarkable degree. In many cases investigations have resulted in a saving of 30 to 40 per cent in lumber and shipping space and at the same time in producing a more serviceable packing case.

The most extensive work on box design and testing has been done in the Forestry Products Laboratories of the Forest Service, U. S. Department of Agriculture at Madison on the campus of the University of Wisconsin. At the Mellon Institute in Pittsburgh investigations upon packing cases have been made and a well-equipped box-testing laboratory has been maintained. Several box manufacturers and box manufacturers' associations have also conducted box-testing investigations. Among these may be mentioned the research department of the Chicago Mill and Lumber Company.

Extent of the Industry.—Of the total annual cut of lumber of approximately 40,000,000,000 ft./b.m., about 6,000,000,000 ft. b.m. are used for boxes and crates. Although box lumber is often a by-product and therefore often less expensive than the longer and more perfect pieces, a conservative estimate of the value of box lumber would be $20 per 1,000 ft. b.m. corresponding to about $120,000,000 per year for the lumber used for boxes. This is in addition to the fiberboard and corrugated fiber cases made from paper waste and wood pulp.

Types of Packing Cases.—Three classes of cases are generally used for food products. These are nailed wooden boxes, wire-bound wooden boxes, and fiberboard (including corrugated fiberboard) boxes. The cut pieces used in box construction are known collectively as "box shook."

NAILED WOODEN BOXES

The nailed wooden box is still an important packing case for fruit and vegetable products, in spite of the popularity of wire-bound boxes and fiber boxes.

[1] Most of the material in this chapter was obtained from Professor E. Fritz of the Forestry Division of the University of California and from articles published by Don L. Quinn in *The Canning Age*. Grateful acknowledgment is made for the information so obtained.

Requirements of a Box.—A box must protect its contents against damage and tampering; it must be serviceable and yet economical; it should be attractive in appearance and permit of printing or labeling, since the packing case is one of the best mediums of advertising.

Causes of Failure of Boxes.—The weakest point in the construction of any box determines its serviceability. The box should be so constructed that all parts are of as nearly equal strength as it is possible to make them.

Frequent causes of failure of boxes are: (1) the use of too few nails; (2) the use of too large nails; (3) the use of too small nails; (4) driving the nails too near the edge of the boards; (5) overdriving the nails; (6) use of ends too thin to hold the nails; (7) ends of boxes not properly reinforced; (8) use of too thin pieces for sides, top, or bottom; (9) use of wrong species of wood; (10) use of too many pieces; and (11) use of unseasoned lumber.

General Specifications for Nailed and Lock-corner Wooden Boxes.—The Forestry Products Laboratory, the canners, wholesale grocers, and box manufacturers in conference with the Consolidated Classification Committee of the transportation companies, adopted definite specifications for nailed and lock-corner boxes. These specifications, although not final, represent a very important advance in the standardization and improvement of box construction. The complete, revised specifications may be obtained from the Forestry Products Laboratory, Madison, Wis. A few of the more important sections of the specifications are given herewith.

Material.—Under average conditions, thoroughly seasoned lumber has a moisture content of 12 to 18 per cent, based on the weight of the wood after oven drying to a constant weight.

Grouping of Woods.—The principal woods used for boxes are classed for the purpose of specifications in four groups:

Group I

White pine	Willow
Norway pine	Noble fir
Aspen	Magnolia
Spruce	Buckeye
Western (Yellow) pine	White fir
Cottonwood	Cedar
Yellow poplar	Redwood
Balsam fir	Butternut
Chestnut	Alpine fir
Sugar pine	Lodgepole pine
Cypress	Jack pine
Basswood	

GROUP II

Southern yellow pine
Hemlock
North Carolina pine
Douglas fir
Larch (Tamarack)

GROUP III

White elm
Red gum
Sycamore
Pumpkin ash
Black ash
Black gum
Tupelo
Maple, soft or silver

GROUP IV

Hard maple
Beech
Oak
Hackberry
Birch
Rock elm
White ash
Hickory

Thicknesses of Lumber.—The thicknesses called for in specifications for boxes of any given commodity will, unless otherwise stated, be understood as applying to Groups I and II woods. Where the material is specified (for woods of Groups I and II) as not more than ½ in. thick and not less than ¼ in. woods of Groups III and IV may be used ¹⁄₁₆ in. less in thickness; where the material is specified (for woods of Groups I and II) as more than ½ in. thick and not more than 1 in., woods of Groups III and IV may be used ⅛ in. less in thickness; where the material is specified (for woods of Groups I and II) as more than 1 in. thick and not more than 2 in., woods of Groups II and IV may be used ¼ in. less in thickness.

Width of Material.—The maximum number of pieces allowed in any side, top, bottom, or end of a box shall be as follows:

Width of Face	Maximum Number
4 in. and under	1
4 to 7 in., inclusive	2
7 to 10 in., inclusive	3
Over 10 in. to average not less than 3 in. wide and no piece to be less than 1½ in. wide at either end if matched, not less than 2 in. wide if butt jointed.	

Surfacing.—The outside surfaces of boxes must be sufficiently smooth to permit of legible marking.

Suitability of Various Woods.—For dried fruits and other fruit products not sealed in airtight containers, the box must be made of wood that will not impart a foreign odor or flavor to the product.

In general, wood for boxes should be light, tough, of good nail-holding power, resistant to splitting, low in resin, free from objectionable odors, soft, and easily worked and should possess an attractive surface that will permit printing and will take label paste. In addition, the price must not be excessive. Some woods are suitable for heavy crates but split badly or exhibit other undesirable qualities when used for boxes.

The western yellow pine, often known to the lumberman as "white" pine, is one of the most important box lumber woods in the United States. About 1,500,000,000 ft. b.m. of this lumber are cut in California per year for boxes, much of it by mills owned by the fruit growers' and packers' organizations of California. The western yellow pine is available from South Dakota and Texas to the Pacific Ocean.

The eastern white pine is used extensively in New England and the Lake states and the southern yellow pine is a very important box lumber tree of the southern United States.

In the Pacific northwest the Sitka spruce is used very generally for boxes, the box lumber usually being a by-product from mills producing lumber for other purposes.

"Oregon pine" or Douglas fir is too heavy and splits too easily to render its use for boxes advisable. It is, however, one of the most important trees now cut for lumber for general purposes. Redwood, a very important Pacific coast lumber tree, is not tough enough for boxes and splits easily.

The hardwoods, oak, ash, maple, birch, etc., are generally too costly for use in boxes. They are also very hard and are difficult to nail.

In general, it may be said that the pines are by far the most important source of box lumber and of these the western yellow, the southern yellow, and eastern white pine are the most widely used.

Revolving-drum Box Tester.—In the Forestry Products Laboratory at Madison, Wis., a large revolving drum has been used to imitate the shocks and handling met by boxes in transit. This drum is shown in Fig. 100.

It is of hexagonal form, each face of the hexagon being 7 by 8 ft. The drum is 14 ft. in diameter across the corners, weighs approximately 27 tons and will test boxes up to 4 ft. in each dimension and weighing 1,000 lb. or less.

The drum rotates at the rate of 1 r.p.m. Each inner face of the hexagon is fitted with a projection which carries the box to a definite height before it drops to the floor of the revolving drum (see Fig. 100).

The drum tester is used in determining the effect of various methods of nailing boxes, of reinforcing the ends or sides, the suitability of various woods, and other factors.

Since the different boxes are subjected to the same treatment in the drum, it has been possible, from the number of falls which are required to cause failure, to determine the relative strength of the boxes in terms of per cent. From the drum test, drop test, and other laboratory data engineers of the Forestry Products Laboratories have been enabled to design boxes for many products that are lighter, require less wood and are stronger and cheaper than boxes formerly in use.

Drop Test.—This test is frequently used to compare the strength of different species of woods used in box construction. The box to be tested is elevated to a definite height above a heavy cast-iron plate and is dropped repeatedly until failure occurs. The boxes are dropped from different positions so that the resistance to impact applied to ends, sides, top, bottom, and corners is determined.

Compression Test.—Boxes often fail because of the pressure of other boxes piled above them or because of other stresses and strains occurring

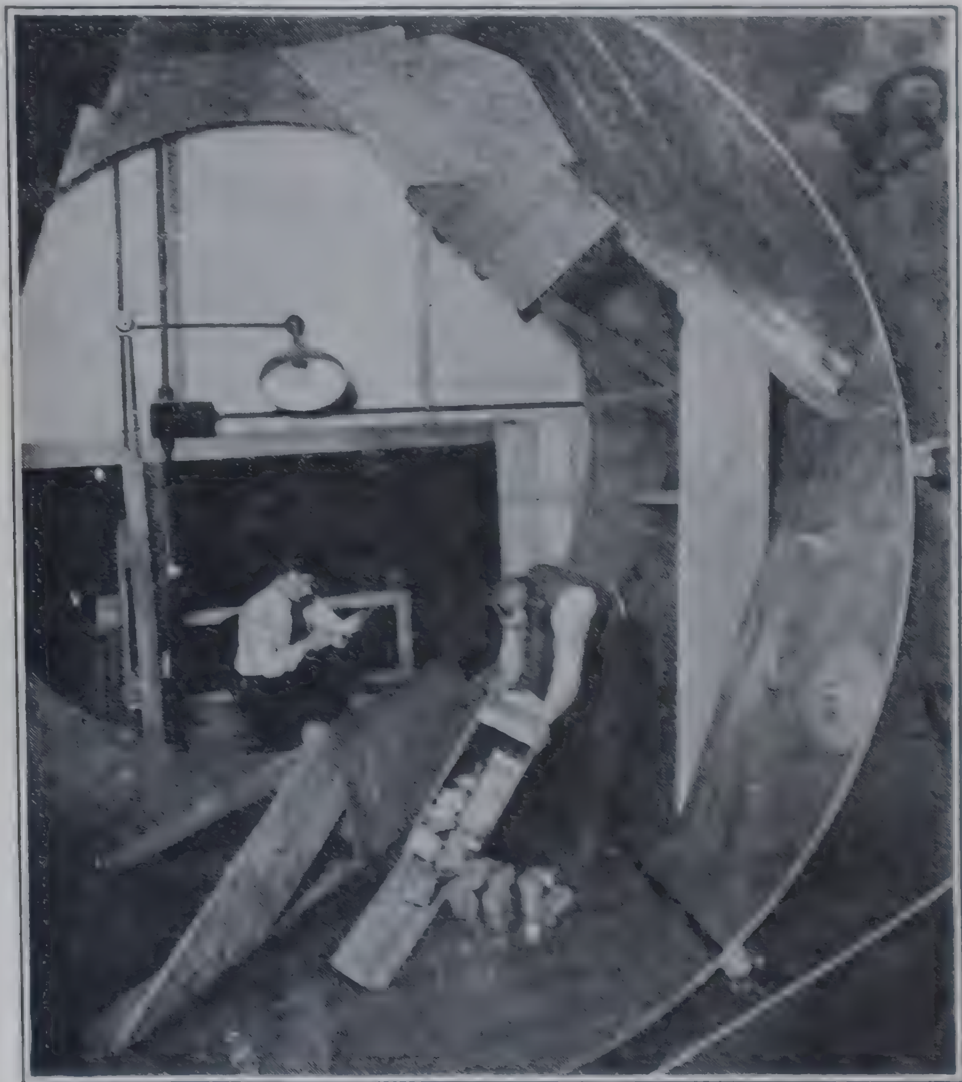

FIG. 100.—Failure of canned goods box in box-testing drum. (*Forest Products Laboratory, Madison, Wis.*)

during loading of cars and holds of ships and during shipment by rail, truck, or boat. In order to simulate these strains, pressure is applied to empty boxes in a press similar to a fruit juice press in appearance. The floor of the press is the platform of a scales, and the pressure upon this platform is recorded by a beam and weights. Pressure is applied until the box fails and the pressure at the time of failure is recorded.

In some tests pressure is applied endwise, in others cornerwise, and in others to the sides or top of the box. Its behavior under different types of strains can thus be studied.

Nail-holding Power of Various Woods.—The Forestry Products Laboratory has made a careful study of the nail-holding power of various woods, and the principal conclusion drawn is that the nail-holding power is proportional to the density of the wood. Density is a function of the percentage of wood substance, exclusive of resin and water possessed by the wood. The results of the above-mentioned investigations are shown graphically in Fig. 101.

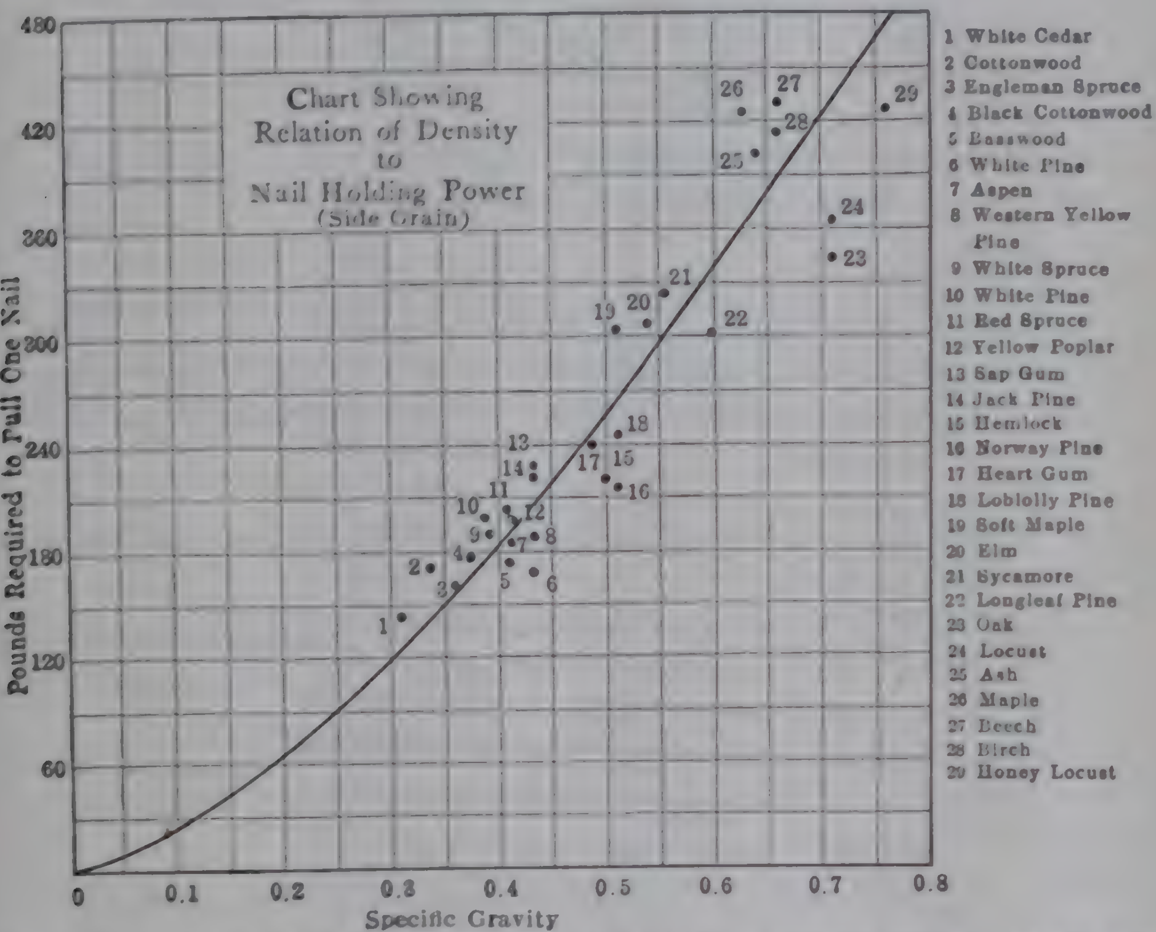

FIG. 101.—Relation of nail-holding power to density of various woods. (*After Forest Products Laboratory, Madison, Wis.*)

Effect of Moisture Content and Storage on Box Strength.—The Forestry Products Laboratory at Madison has found that the moisture content of wood at the time of nailing affects the strength of boxes to a surprising degree. Boxes made from green lumber were found to suffer marked decrease in strength after 1 week's storage. If green or wet lumber is used, it dries after the box is made, and the wood shrinks away from the nail, thus enlarging the hole and weakening the nail-holding power of the wood.

The best results were obtained by use of lumber thoroughly seasoned under conditions to which the boxes were to be subjected in storage. Thoroughly air-dry lumber of 12 to 15 per cent moisture gave good service.

Nails.—Nails must be driven closely enough together to give the desired structural strength to the box and yet not cause splitting. The number of nails used greatly affects the strength of the box. The Forestry Products Laboratory found in one box making test, with boxes of sizes used in canning, that five nails gave 50 per cent greater strength than four nails, and six nails 100 per cent greater strength than four nails. Use of a sufficient number of nails increases the strength of the box and permits the use of lighter pieces.

Cement-coated nails were found to have from 10 to 30 per cent greater holding power than plain nails, and long, slender nails were found superior in holding power to short or thick nails.

The general rule suggested by the Forestry Products Laboratory for the sizes of nails for different woods is as follows:

> For woods of medium hardness, the "penny" of the nail must not be greater than the thickness, in eighths of an inch, of the wood which holds the point of the nail. In the case of softer woods, nails may be one "penny" larger and sometimes even two "pennies" larger. With hard woods, nails should be one "penny" smaller than called for by woods of medium softness.

The head of the nail should be broad and heavy to prevent its being pulled through the wood.

Nails driven into the side grain of the wood possess a greater holding power than when driven into the end grain. On this account nails should be driven closer together in the latter case.

Nails should be driven squarely into the center of the end of the box to give maximum holding power, to prevent splitting, and to prevent them from coming out of the wood.

Overdriving greatly reduces the holding power of nails. They should be driven flush but should not be given an "extra tap."

The Forestry Products Laboratory has also found that nails driven at an angie of about 15 degrees hold very much better and give stronger boxes than nails driven vertically.

Spacing of Nails.—The spacing of nails is of great importance. A rule suggested for the spacing of nails in boxes is the following:

> For "six-penny" or smaller nails held in the side grain, there should be a spacing of 2 inches and for the same nail in the end grain a spacing of 1¾ inches. For larger nails the spacing should increase ¼ inch for each additional "penny" of the nail used.

This spacing is closer than that given by the average box-nailing machine, but is necessary in order to balance the strength of the box properly.

Nailing Schedule.—The National Association of Box Manufacturers has approved the sizes of nails given in the following schedule. Cement-coated nails are specified.

The Forestry Products Laboratory has recently approved a modified nailing rule which is as follows:

When the thickness of the sides, tops and bottoms used is less than three-fourths the thickness of the parts determining the size of nail to use, then the nails may be one penny smaller than specified in the schedule. When the thickness of the sides, tops and bottoms used is the same as the parts determining the size nail to use, then the nail may be one penny larger than specified in the schedule.

TABLE 79.—NAILING SCHEDULE FOR BOXES

Group of wood	Thickness of ends or cleats in inches							Thickness of sides to which top and bottom are nailed		
	7/16	1/2	9/16	5/8	3/4	13/16	7/8	1/2	9/16	5/8–7/8
I	5d	5d	6d	7d	8d	8d	9d	4d	5d	7d
II	4d	5d	5d	6d	7d	7d	8d	4d	5d	6d
III	4d	4d	5d	5d	6d	7d	7d	3d	4d	5d
IV	3d	4d	4d	4d	5d	6d	7d	3d	4d	5d

WIRE-BOUND BOXES

Wire-bound boxes are made of relatively thin pieces of lumber held together by wires which pass completely around the boxes and give them greater strength than is possible by nailing. This box is elastic rather than rigid and offers greater resistance to shock than the nailed box. It has been adopted by several large food products manufacturers for export use in preference to the nailed box or fiberboard carton.

The Forestry Products Laboratory favors the use of this type of box because it uses less lumber than the nailed box and often that which is unfit for nailed boxes.

Advantages.—Quinn has enumerated the advantages of the wire-bound box as follows:

1. Wire boxes weigh 25 to 50 per cent less than nailed boxes. . . . The saving in space in export shipments amounts to about 5 per cent when wire-bound boxes are used.
2. Fewer losses from breakage result from use of wire-bound boxes.
3. The cost of making up wire-bound boxes does not exceed one-third the cost of making up nailed wood boxes.
4. Pilfering is greatly reduced by use of this type of box because it is impossible to open it in transit without such tampering being easily detected.

5. The packing of boxes for shipment is facilitated because the boxes are assembled at the point in the factory where they are to be used.

6. Wire-bound boxes will withstand great pressure, making it possible to stack the filled boxes to any desired height in the warehouse or boat hold without fear of collapse.

7. The wire-bound box is adaptable and can be built to meet any requirements for canned goods and similar products.

A disadvantage of wire-bound boxes is their liability to puncture by other boxes or by contact with sharp projections of any sort. The thin pieces used in the sides, tops and bottoms are not very resistant to this hazard. However, boxes to be subjected to such hazard may be made of heavier material.

Comparative Strength of Wire-bound and Nailed Boxes.—A thorough study of wire-bound boxes has been made at the Rockaway Laboratory of the 4-One Box Machine Makers and the 4-One Association of Wire Bound Box Manufacturers, by A. K. Armstrong.

In one series of tests a wire-bound box built of Douglas fir was 500 per cent stronger than a nailed box of the same capacity built of western yellow pine. A wire-bound spruce box was 1,089 per cent stronger than the nailed box and approximately 100 per cent stronger than the wire-bound Douglas fir box. The material used in the wire-bound boxes was much lighter than that used in the nailed boxes.

Method of Making Wire-bound Boxes.—The wood used for the sides, tops, and bottoms of wire-bound boxes is called "sheet material," and for domestic service is usually ⅛ in. in thickness.

The food manufacturer receives the wire-bound boxes with the sides, top, and bottom in flat form joined together by stapled wire. This is known as the blank or mat and consists of four sections. The individual pieces are "sewed" or stapled in an automatic wiring and stapling machine at the box factory. The ends of the blank are attached to cleats by staples which are astride the wires and which pass through the side, top, and bottom pieces into the cleats.

The ends consist of single pieces to be fitted to the ends of the blank after the latter is folded to form the bottom and sides of the box.

The filled box is sealed by folding the top into place and twisting the ends of the binding wires securely together by a small wire-tying machine.

Specifications.—Tentative specifications for wire-bound boxes for food products have been established by the 4-One Association of Box Manufacturers and the American Society for Testing Materials. Some of the more important points of these specifications are the following:

1. General Form. The boxes knocked down shall consist of four separate sections forming top, side, bottom and side, connected only by continuous steel binding wires; and of separate ends.

Each of the separate sections forming the sides, top and bottom shall consist of cleats, thin boards, wire and staples. The four sections shall be separated such a distance from each other that the wires shall be in tension when the sections are folded.

2. Woods are placed in four groups as for nailed boxes.

3. Cleats shall be not less than $\frac{3}{4}$ of an inch thick (parallel to the length of the box) and not less than $\frac{7}{8}$ of an inch in width.

4. The thin boards shall be sound, free from decay, well seasoned and cut so that adjacent faces of boxes will be at right angles to each other. When the thickness of thin boards as specified is less than $\frac{3}{16}$ of an inch, thin boards made of woods of Group III and IV may be $\frac{1}{32}$ of an inch less than the specified thickness, except that the minimum thickness of thin boards of any kind of wood shall be $\frac{1}{8}$ inch.

5. Thin boards less than $2\frac{1}{2}$ inches in width at either end shall not be used.

6. Staples shall be of annealed wire of not less than No. 16 gage.

The staples on end wires shall be driven astride the binding wires, through the thin boards into the cleats and firmly anchored. The space between staples shall not exceed $2\frac{1}{2}$ inches, except for woods of Group III and IV where the space between staples may be $\frac{1}{4}$ inch greater than the above distance.

FIBER BOXES

Quinn states that more than $6,000,000,000 worth of various commodities are transported each year in fiberboard containers. Fiberboard boxes are light, convenient to use, attractive in appearance, and effect a great saving in wood.

Fiberboard.—Fiberboard used in the construction of boxes is of two general types, solid and corrugated. Solid fiber is built up of layers of heavy paper cemented together by silicate of soda. The outer layers are of "jute" board, *i.e.*, heavy tough paper, while the center is built up of lighter and weaker materials. The various sheets vary from 0.016 to 0.03 in. in thickness and the board made up of the individual pieces cemented together is of three standard thicknesses, 0.060, 0.080, and 0.100 in., known as "60-point," "80-point," and "100-point" board.

Corrugated board differs from solid fiberboard in that the interior is made up of a trusswork of relatively thin straw paper, which imparts a cushioning property to the board and makes it a desirable package for glass containers.

Using the Box.—The board is cut and folded at the factory and delivered in collapsed form to the canner or other user, who opens the box, seals or staples the bottom, fills the box, and seals or staples it. Sodium silicate is the usual adhesive used in sealing bottoms and tops. It possesses great binding strength, is cheap, and dries fairly rapidly. When dry it resists water and other liquids and gives a permanent union.

Fiber boxes are also frequently sealed with strips of adhesive tape.

Advantages of Fiber Boxes.—Fiber boxes use only about one-sixth as much wood as ordinary boxes and much of this represents waste board or paper used for the second time. The inner portion of corrugated fiberboard is to a great extent made from paper pulp prepared from waste wheat straw. For these reasons fiberboard conserves wood and thus tends to decrease the drain on the nation's forests.

Fiber boxes are cheaper than nailed or wire-bound boxes, and the small operator requires no special nailing machine or other special equipment for sealing. The transportation charges for both the empty and the filled boxes are less than for other types of boxes and smaller storage space is required.

The assembling cost at the cannery or other food establishment is low. With a small inexpensive machine one man can seal 150 to 300 boxes per hour and with a large machine several thousand per hour.

Fiber boxes are much less liable than other boxes to cause injury to employees. Pilfering is much less common with fiber containers than with nailed boxes because of the difficulty of concealing tampering.

Corrugated board is a good shock absorber, and on this account boxes made of this material are preferable to other boxes for glassed goods.

Fiber boxes take printing and lithographing very satisfactorily and provide a valuable advertising medium for food products.

Durability and Strength.—There is less variation in the strength of fiber boxes than nailed boxes, consequently the average strength of the former need not be so great. Nevertheless there is rather wide variation in the behavior of fiber boxes in shipment, because of improper sealing and improper stacking in the car. In overseas shipping tests made during the World War, fiberboard and corrugated fiberboard boxes gave good service when not wet in transit.

Disadvantages.—They are not so rigid as nailed or wire-bound boxes and in general not so durable. Being made of wood pulp they are less resistant than nailed boxes to puncture.

The fiber box does not withstand storage well in the rain, in wet holds of vessels, or in other positions where it may become water-soaked, but progress is being made in developing water-resisting board.

Sealing Fiber Boxes.—Tests at the Mellon Institute show that effectiveness of sealing depends very largely upon securing good contact of the flaps with the top and bottom of the boxes. Where automatic machines are used, sealing is generally well done, but hand-sealed boxes are frequently poorly sealed.

It was found that the boxes did not reach maximum strength at room temperature after sealing with sodium silicate in less than 4 hr., but when sealed and held at 120°F., maximum strength was attained in 5 min.

Pressure on the boxes after sealing and during drying of the silicate is desirable in order to give maximum strength to the box. Fiberboard requires greater pressure than corrugated board because of the greater difficulty in "ironing out" uneven areas in the former.

Two types of tape, kraft and cambric, are used in sealing fiber boxes. The cambric tape is much stronger and gives a more durable seal.

If the sides are improperly scored, the flaps do not make good contact with the top and bottom, causing imperfect sealing and frequent failure of such boxes. The sides should be so scored that the underside of the flap does not crease on bending.

Stacking Fiber Boxes.—These boxes are difficult to stack and are liable to topple. If strips of wrapping paper are laid across the tops of the stacked boxes between each tier of five boxes and if wooden strips are laid on the boxes near the edges of the stacks, the boxes stand well.

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CHAPTER XXX

WINES

As at present defined by Federal regulations, wines are the fermented juices of various fruits; all wines, except those made from grapes, must be labeled with the name of the fruit used. The word "wine," unqualified, signifies the fermented juice of the grape. The fermented juice of apples is generally known as "cider" or "hard cider" and that of pears as "perry," but they may also be called "apple wine" and "pear wine." A wine-like drink, "saké," is also made in the Orient from rice; and in some parts of the world honey is used in preparing an alcoholic beverage known as "mead."

The first and greater portion of this chapter is devoted to true wines, *i.e.*, those made of grapes. The last portion of the chapter considers other wines, particularly those made from apples, citrus fruits, and berries.

Definitions and Regulations.—The United States federal food and drug regulations give the following definitions and standards for wines. Dry wines offered for sale must meet the following federal and state standards:[1]

Wine is the product made by the normal alcoholic fermentation of the juice of sound ripe grapes, and the usual cellar treatment, and contains not less than 7 per cent nor more than 16 per cent of alcohol by volume, and in 100 cubic centimeters (20°C.), not more than 0.1 gram of sodium chloride nor more than 0.2 gram of potassium sulfate; and for red wine not more than 0.14 gram and for white wine not more than 0.12 gram of volatile acids produced by fermentation and calculated as acetic acid. Red wine is wine containing the red coloring matter of the skins of grapes. White wine is made from white grapes or the expressed fresh juice of other grapes.

Dry wine is wine in which the fermentation of the sugar is practically complete, and which contains in 100 cubic centimeters (20°C.), less than 1 gram of sugars, and for dry red wine not less than 0.16 gram of grape ash and not less than 1.6 grams of sugar-free grape solids, and for dry white wine not less than 0.13 gram of grape ash and not less than 1.4 grams of sugar-free grape solids.

Ripe California wine grapes will yield wines that are well within the federal and international standards. The regulations as to volatile acid content must be carefully observed, since the volatile acidity of wines serves as an index of soundness.

[1] Definitions and standards for food products, *U. S. Dept. Agr., Food and Drug Administration, S.R.A., Food and Drug* 2 (4th rev.), 1–20, 1933.

Fortified dry wine is wine to which brandy has been added but which conforms in all other particulars to the standards for dry wine. . . .

Sweet wine (without further qualification) is wine in which alcoholic fermentation has been arrested, and which contains in 100 cc. (at 20°C., 68°F.) not less than one gram of sugars, and for red sweet wines not less than 0.16 grams of grape ash, and for sweet white wine not less than 0.13 grams of grape ash. . . .

Fortified sweet wine is wine to which wine spirits (wine brandy) have been added. By act of Congress wine spirits and sweet wine are defined as follows: "That the wine spirits mentioned in section 42 of this act is the product resulting from the distillation of fermented grape juice to which water may have been added prior to, during, or after fermentation for the sole purpose of facilitating the economical fermentation or distillation thereof, and shall be held to include the products from or their residues commonly known as grape brandy; and pure sweet wine which may be fortified free of tax, as provided in said section, is fermented grape juice only, and shall contain no substance added, introduced before, during or after fermentation, except as herein expressly provided; and such sweet wine must contain not less than four per cent of saccharine matter, which may be tested by Balling's saccharometer or must scale, after evaporation of the spirits contained therein and restoring to original volume by the addition of water; provided, that the addition may be made of pure boiled or condensed grape must, or pure crystallized cane or beet sugar to the pure grape juice, or fermented juice, prior to the fortification provided in this act for the sole purpose of perfecting sweet wine according to commercial standards." (Note: Water may be added only as necessary to operation of conveyors, etc., or not to exceed 10 per cent; sugar may be added not to exceed 10 per cent; and the wine before fortification must contain not less than 5 per cent of alcohol by volume.)

For further details see "Gauger's Manual," present cost $1.00 and "Regulations 7," cost 50 cents obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C.

Sparkling wine (Champagne, sparkling Burgundy, etc.) is wine in which the after part of the fermentation is completed in the bottle, the sediment being disgorged and its place being supplied by wine or sugar liquor, and which contains in 100 cc. (at 20°C., 68°F.) not less than 0.12 grams of grape ash.

discharge

Note: Much sparkling wine is now made by fermentation in bulk by the Charmat process as later described. It may be called sparkling wine but not Champagne unless suitably qualified.

Carbonated wine is wine artificially charged with carbon dioxide (carbonic acid) gas.

Modified wine, ameliorated wine, corrected wine is the product made by the alcoholic fermentation with the usual cellar treatment, of a mixture of the juice of sound ripe grapes with sugar (sucrose), or a syrup containing not less than 65 per cent of sugar (sucrose) and in a quantity not more than enough to raise the alcoholic strength after fermentation to eleven per cent by volume.

"Raisin wine is the product made by the alcoholic fermentation of an infusion of dried or evaporated grapes, or a mixture of such infusion, or of raisins, with grape juice." *Note:* Much raisin wine is made in certain Southern and eastern states in the home or in small so-called "wineries"; the product is usually poor and rarely deserves the name of "wine."

Additional regulations and standards have been set, since repeal of the Eighteenth Amendment, by the Federal Alcohol Administration, the Alcohol Tax Unit of the Internal Revenue Department and by various state authorities. For example in California the State Board of Health has ruled that red wine offered for sale must not contain more than 0.120 gram volatile acid per 100 cc. and white wines not more than 0.110 gram per 100 cc.; fortified sweet wines must contain at least 18 per cent of alcohol, and minimum standards are set for the Balling degree of various fortified wines. Brandy made from raisins is permitted for use in fortification of sweet wines. For further details apply to the California State Board of Health, Wine Inspection Service, State Building, San Francisco, Calif.

In addition to the various specific regulations presented in this section, the general provisions of the State and Federal Food and Drug Act and Regulations apply in respect to labeling, net contents of containers, purity, freedom from toxic substances, etc. It is generally assumed in the industry that the presence of sulfur dioxide need not be declared unless it exceeds 350 p.p.m.; however, its presence is declared on Sauterne wine bottles even if less than 350 p.p.m.

Above 22 per cent alcohol content the wine tax rapidly increases in proportion to alcohol content. Beverages cease to be wines and become cordials, liqueurs, etc., when the alcohol content becomes much above that of fortified wines, and the products must then be made in premises separate from a winery; their manufacture being considered "rectification" rather than "wine making."

The prospective wine producer is advised to consult his state and federal wine regulatory officials before making any other preparations whatsoever toward establishing, purchasing or operating a winery, distillery, or rectifying plant; as the regulations are complex and the penalties extremely severe.

Classification of Wines.—Wines are classified in several ways, *e.g.*, according to origin, as French, Spanish, Italian, German, Californian, New York, etc., or to character, as sweet and dry (nearly free of sugar); red and white; sparkling and still; heavy, medium, and light wines; or as natural and as fortified. The following list of wine types and kinds is not comprehensive, as space does not permit detailed classification, and is offered merely to indicate the general commercial manner of classifying wines.

1. *Dry Red Wines.* *a. Bordeaux Type.*—Some of the finest red wines of the world are produced near Bordeaux, such for example as Chateau Lafite, Chateau Margaux, Chateau Latour, Chateau Mouton Rothschild, and Chateau Haut Brion. Color, medium deep. High tannin. Medium alcohol content. Usually made (in France) from Cabernet grapes. In other countries so-called Bordeaux-type wines are made from several varieties of red wine grapes of which the Cabernet is the best known. The Bordeaux district is subdivided into eight districts, *viz.*, Côtes, Entre-Deuxmers, and Palus, which produce ordinary wines; and the following fine wine districts; Graves, producing fine Clarets and dry white wines; Sauternes, producing sweet white wines; Saint-Émilion, producing fine dry red wines; Pomerol, producing fine dry red wines; and the Medoc, producing the finest dry red wines. The districts are subdivided into communes. For example, Saint-Julien is a commune in the Medoc, famous for its red wine.

b. Burgundy Type.—The real Burgundy wines of France are made in the Burgundy district (Côte de Nuits and Côte de Beaune) of the Pinot Noir grape. They are of fairly high total acidity, medium color, medium tannin content, and high sugar-free extract and have the typical flavor of the Pinot. Burgundy-type wines made in other countries seldom are made of the Pinot and are usually of deeper color, lower in acidity, and neutral in flavor and bouquet, compared with the true Burgundies of France. Famous Burgundies are Chambertin, Clos de Vougeot, Hospices de Beaune, Romanée-Conti, Les Saint Georges, Pomard, Alox-Corton, and Meursanet. Montrachet and Pouilly are famous white Burgundies.

c. California Claret.—A light, red dry wine of California probably intended to resemble the medium quality, red Bordeaux wines. As produced in California, it is made of various red wine varieties. Generally it is the lowest priced red wine; a common, table wine, but a pleasing, wholesome beverage when properly made.

d. Rhone or Côte du Rhone Wines of France, made in the Rhone Valley, warmer sections. "Hermitage" and "Chateau Neuf du Pape" are very famous Rhone wines. Heavy in color and body. Rich in flavor, often berry-like in flavor and aroma. The true Petite Sirah grape is used for the more famous of these wines. Mature slowly. Some Californian Burgundy-type wines resemble the Rhone Valley wines in composition and somewhat in flavor.

e. Chianti Wines.—The real Chianti wines are made in north-central Italy in Lombardy in a limited area. Chianti-type wines are made in California. They are rather "rough" (high in tannin); of medium acidity and of medium to rather light red color. Properly made they are good table wines.

f. Barbera, a heavy red wine of the Piedmont district of Italy. Owes its character to the quality of the grape as well as the locality. Rich in flavor. Also made in California from this variety.

g. Vin Ordinaire of France.—This name is applied to low-priced common bulk and table wines of France. Usually consumed young, less than 1 year old. It is the national beverage of France, Italy, Spain, and many other Mediterranean countries. It may be red or white; many varieties of grapes are used in its production. California, Argentina, Chile, North Africa, Australia, and South Africa also produce such wines. Only a small proportion of the output is of fine quality. It is the "backbone" of the wine industry.

h. Red Wines Named after Varieties of Grapes.—There are many such wines. This method of naming wines is very commendable. Well-known red wines with varietal names are the following: Barbera, Zinfandel, Cabernet, Pinot, Concord, and Valdepeñas (also name of a district in Spain famous for its red wine).

i. Blending Wines.—North Africa produces heavy red wines much in demand in France for blending with French wines of lower alcohol and higher acid content. California and other warm grape regions also produce such wines.

2. *Dry White Wines. a. Chablis.*—Made in the Chablis district near Burgundy in France of the Pinot grape. Possesses a high total acidity, a "flinty" taste, a marked Pinot aroma, and light color. Chablis-type wines are made elsewhere, usually from other varieties than the Pinot. Often, in other countries than France, little or no distinction is made between the Chablis and Riesling of a given district.

b. Riesling.—Made from one or a mixture of the Riesling varieties of grapes. The type Rieslings are from the Rhine wine district of Germany, although Riesling wines are made from Riesling grapes wherever they may be grown. The best-known Rieslings are of high acidity, very low sugar content, medium to low alcohol content, and very light color. There are also sweet unfortified wines made from Riesling grapes in Germany, either from grapes allowed to partially dry on the vines or from those attacked by the "noble mold," *Botrytus cinerea*. The Moselle Valley and Alsace are noted also for their dry white wines made of Riesling grapes. True Riesling wines are very fruity in aroma and flavor.

c. Hoch.—Probably derived from Hochheim, a famous dry white wine town of the Rhine. Very dry white wines of high total acidity, medium to low alcohol content, and of light color. A name commonly applied in England and America to "Rhine-wine" type white wines of light color, high total acidity, and medium to low alcohol content.

d. Moselle or Mosel.—Dry white wines similar to Hoch in composition and character from the Moselle Valley of Germany. Wines of similar

type are produced in other countries, including California and Chile; but too often no distinction is made between Chablis, Riesling, Hoch, and Moselle.

e. Dry Sauterne.—A California white wine of amber color, rather high alcohol content, and much lower sugar content than the usual Sauterne wine of France. Should be made of Semillon or Sauvignon varieties or a blend of the two.

f. White Graves.—Famous dry white wine produced in Graves district near Bordeaux, France. Somewhat less acid than Moselle and the Rhine wines.

g. White Burgundy.—Made of the Pinot grape, usually in Burgundy. Medium high acidity and rich bouquet and flavor. Montrachet and Pouilly are famous white Burgundies.

h. Varietal Names.—In addition to Riesling a number of other white varietal names are used, such as, Gutedel, Burger, Traminer (German varieties), Chasselas, Muscat, or Moscato, etc.

3. *Sweet Unfortified Wines.*—Both red and white unfortified sweet wines are produced although the former (particularly the Sauternes) are the better known in America.

a. Sauternes.—These sweet, unfortified white wines are produced in the Sauternes district near Bordeaux, France, although Sauterne-type wines are made in California, Chile, Australia, and elsewhere. The name has come to signify a class or type rather than wine from the specific Sauternes area of France (much to the displeasure of the producers of that area). In France Sauterne is made of the Semillon, Sauvignon Blanc, and Sauvignon Vert varieties. In other countries these varieties are often replaced with others. Sauternes of France are preserved with sulfur dioxide in order to prevent fermentation of the residual sugar. The most famous Sauterne wine is Chateau d' Yquem, a very sweet Sauterne of high bouquet and flavor produced from grapes of one small vineyard of that name. Sauternes are essentially dessert wines.

b. Sweet Rhine Wines.—In certain seasons grapes in the Rhine wine district attain high sugar content by partially drying on the vines or by concentration of the must by growth of the Botrytus mold growing on the grapes on the vine as in the Sauternes district. The bunches and éven individual berries are carefully sorted, and from the sweetest, partially dried grapes is made the famous, very costly sweet wines of the district.

c. Straw Wines.—In some districts in France some of the grapes are partially dried to increase their sugar content, giving wines that are high in alcohol and in some cases sweet. They may or may not be fortified by addition of brandy. In Spain a similar practice is followed in the Jerez district, although the wines are usually fortified, if for export. Undoubt-

edly this process could be used successfully in California. The writer has partially dehydrated grapes lightly treated with sulfur dioxide and prepared wines from them of the German and sweet straw-wine types. The Muscat, Palomino, Sauvignon, and Zinfandel varieties responded well to this procedure.

d. Tokay (*Tokaj*).—A famous sweet wine of Hungary. Not made from the grape variety known as Tokay in California; but chiefly from the Furmint grape of Hungary. The grapes are allowed to partially dry on the vines before crushing. Brandy is not added.

e. Orvieto.—A noted sweet wine of central Italy, popular with visitors from other countries.

f. Aleatico.—A sweet, usually unfortified wine made in Italy from red Muscat grapes (Aleatico or Alleatico variety). Red to pink in color. As made fróm the same variety in California, it is preserved with sulfur dioxide. Also an Aleatico type is made in California by mixing red wine grapes and white Muscat grapes or their wines.

g. Other Unfortified Sweet Wines.—Often Italian wine makers in California prepare sweet, unfortified white Muscat wines and sweet, unfortified red wines (sweet "Clarets") from very ripe grapes. In most other wine-producing countries similar wines are also produced.

By the syruped method of fermentation described by Cruess and others, it is possible to prepare unfortified sweet wines of 16 to 18.5 per cent alcohol. The method is used commercially for berry wines.

4. *Fortified Wines.*—These are wines, usually sweet, to which alcohol (grape brandy of high proof) has been added to increase the alcohol content to about 20 to 21 per cent.

a. Sherry.—Formerly, this name applied only to wines produced in the Jerez de la Frontera district of Spain, but it is now a wine class name used for Sherry-type wines produced in other countries as well as those of Spain. Low to medium sugar content; usually less than 5 per cent for Californian Sherries. In Spain, Sherries are made principally from the Palomino and Pedro Ximenez grapes, and the process involves use of certain film yeasts and the Solera system (see later discussion). In California other varieties of grapes are used, and the fortified wine is baked to impart the "Sherry" taste (see later). Sherry varies from pale amber to deep brown in color.

b. Madeira.—True Madeira is a fortified sweet wine from the Island of Madeira off the coast of Portugal. As made elsewhere, it is a baked, sweet, fortified wine made in much the same manner as California Sherry or is a blend of Sherry and Angelica. It is sweeter than Sherry and amber to brown in color.

c. Port.—Formerly true Port was produced only in a small area (the Douro) of Portugal. At present the name is applied to similar wines also

produced in other countries. Red to "tawny" in color. Fortified. Aged at normal cellar temperature.

d. Angelica.—A Californian name and product. A fortified, sweet wine of light color and rather neutral flavor. Usually made of Malaga, Thompson Seedless, or Tokay grapes. Not baked.

e. Muscatel.—A fortified, sweet, white wine made from the white Muscat (a raisin grape variety). Pale in color to amber. Very aromatic, with the characteristic Muscat aroma and flavor. Usually not baked or only lightly so.

f. Marsala.—An artificially flavored, baked, sweet wine made in Sicily. Very famous as a dessert wine.

g. Other Fortified Wines.—A number of other fortified wines are made in the leading Mediterranean countries, Chile, and elsewhere but will resemble one or another of the types listed above.

Place of Wines in the Menu.—Dry wines are used throughout the civilized world as table beverages with meals, rather than as competitors of distilled liquors. Fortified wines, on the other hand, are consumed as appetizers or as between meal beverages in much the same manner as cocktails and liqueurs.

In the United States the annual consumption of wine per capita before prohibition was about 0.45 gal., of which about 0.20 gal. was dry wine and about 0.25 gal., sweet (fortified). At present the consumption of commercial wines is about 0.40 gal., two-thirds of which is sweet wine and one-third dry wine. There is in addition, however, about 0.25 gal. of dry wine made per capita in the home, bringing the total per capita consumption to about 0.65 gal. per capita. The total consumption, in other words, is about 54,000,000 gal. of commercially made and about 30,000,000 gal. of homemade wine per year.

In France and Italy the annual consumption of wines is in excess of 25 gal. per capita; but it is very much lower in Great Britain, Russia, Germany, and Scandinavia. Race and climate evidently have a marked bearing on beverage habits, the people of Northern European countries preferring beer and distilled beverages and the Mediterranean countries, dry wines.

Composition of Grapes.—Grapes contain a considerable number of constituents of importance in the composition and quality of the wine; notably, sugars, tartaric acid, cream of tartar, tannin, anthocyanin pigments, proteins, pectins, phosphates, potassium salts, sodium salts, and various other elements in smaller amounts such as calcium, magnesium, iron, and manganese.

Grapes vary greatly in composition according to variety and maturity. The weight of the berries of wine varieties ranges from about 0.7 gram to

about 4.0 grams. The ranges for seed, skin, and pulp contents are about as follows:

Seeds	1–5.0 per cent
Skins	6.5–10 per cent
Pulp	80–90 per cent

Roos ("L'Industrie Vinicole") gives the following analysis of Carignane grapes:

Density	1.076
Water	77.85 per cent
Sugar	16.12 per cent
Cream of tartar	0.62 per cent
Free acids	0.58 per cent
Soluble nitrogen	0.18 per cent
Mineral matter	0.17 per cent
Crude fiber	0.68 per cent
Not determined	3.80 per cent

The composition of several varieties of grapes grown at Davis in California was determined by H. Davi and the writer.[1] The following analyses are of the musts (juices) of the ripe grapes.

TABLE 80.—COMPOSITION OF MUSTS OF SEVERAL VARIETIES OF RIPE GRAPES GROWN AT DAVIS, CALIF., IN 1914 AND 1915
(Expressed in per cent by weight)

Variety	Balling	Total sugar	Total acid	Protein	Balling minus sugar (sugar-free extract)
Malaga	21.78	19.40	1.07	0.73	2.38
Muscat	23.85	21.52	0.96	0.58	2.33
Burger	19.86	17.44	0.87	0.62	2.42
Cornichon	20.41	18.88	0.84	0.59	1.53
Sultanina	23.20	20.58	0.72	0.62	2.62
Emperor	20.57	18.36	0.75	0.66	2.21
Sultana	23.22	21.13	0.78	0.34	2.09
Pedro Zumbon	23.72	21.10	0.53	0.64	2.62

Grapes grown in a warm climate, such as prevails in most California grape-producing districts, are higher in sugar content and lower in total acidity than those grown in cooler regions such as central and northern France, Germany, Switzerland, and New York.

The sugars in Vinifera grapes (European, "Californian") are the two hexose sugars levulose (fruit sugar) and dextrose (grape sugar), whereas

[1] See *Univ. Calif. Agr. Sci. Ser.*, **3** (6), 1918.

Labrusca grapes (eastern United States) often contain considerable sucrose (cane sugar) in addition to invert sugar.

The acidity of ripe Californian grapes is due chiefly to cream of tartar $KH(C_4H_4O_6)$, d-tartaric acid, $H_2(C_4H_4O_6)$, or $CHOH—CHOH—(COOH)_2$ and l-malic acid $CHOH—CH_2(COOH)_2$. There is also usually a very small amount of citric acid. Tannin also adds slightly to the titratable acidity.

The cream of tartar content of the fresh juice varies from about 0.3 to 0.7 gram per 100 cc., much of which precipitates during and following fermentation, owing to decreased solubility in the presence of alcohol. The free tartaric acid varies from 0 to about 0.6 gram per 100 cc., depending upon the climate where grown, maturity, and variety. Malic acid is abundant in green grapes but rapidly decreases during ripening.

Citric acid is often added to wines, France allowing an addition of not more than 0.05 gram per 100 cc. In the United States its addition is considered common cellar practice and there is no legal limit on the amount that may be added. Grapes contain a small amount of this acid.

Tannin, a slightly acid and very astringent substance, is present in the skins, seeds, and stems; stems containing as much as 2.5 per cent on the fresh basis. It imparts a characteristic flavor (astringency or puckeriness) to red dry wines in which the usual concentration is from 0.10 to 0.25 gram per 100 cc. It is of great importance in the natural clarification and in the fining of wines, as it forms insoluble precipitates with proteins. Also, it greatly increases the stability of wines against clouding from precipitation of proteins; and protects the stability of the color of red wines against precipitation. The tannins of grapes are of the so-called catechol tannin group, *i.e.*, they give the catechol tannin reaction, a green color with dilute solutions of iron salts and yield catechol or orthodihydroxy acids on alkaline hydrolysis.

Some of the "body fullness" of flavor or extract is due to the presence of small amounts of pectic substances and gums. Labrusca varieties are richer than the Vinifera varieties in these substances.

The nitrogenous substances of grapes consist of proteins, and smaller amounts of simpler compounds such as peptones, amino acids, and ammonium salts. Nitrogen compounds are necessary for yeast growth and hence for fermentation. The total nitrogen content ranges from about 0.03 to about 0.12 per cent in the must, or expressed as protein about 0.20 to about 0.75 per cent.

The ash content of must is usually from 0.3 to 0.4 gram per 100 cc. and ranges from about 0.20 to about 0.60 gram per 100 cc. In ashing a sample of must the organic salts are converted into oxides, of which about 40 to 60 per cent is potassium oxide and 8 to 20 per cent is phosphorus pentoxide; the elements potassium and phosphorus are essential for yeast

growth. However, the sodium and potassium oxides on exposure to air are rapidly changed to the carbonates.

As previously stated, climate greatly affects the composition of grapes. In warm climates grapes ripen early, are rich in sugar and low in color and total acidity. In cool climates they ripen late and are apt to be low in sugar and high in total acid content. In very hot sections, as in the Imperial Valley of California, grapes are usually low in both acidity and sugar content, since the average temperature is above the optimum.

Grapes grown on light soils, such as gravelly soils, ripen earlier than on heavy clay soils ("adobe" soils). It is generally believed that grapes grown on calcareous soils, such as those of the Champagne district of France, have more aroma and flavor than those grown on other soils; also that red wine grapes grown on heavy clay soils are apt to be deeper in color, and richer in tannin than those grown on lighter soils, giving "heavier" wines that age more slowly.

Varieties of Grapes for Wine Making.—The grapes used for wine making are for the most part of two species, *viz.*, *Vitis vinifera* (so-called European varieties) and *V. labrusca* (so-called eastern American varieties). Most of the wines of the world are made of *V. vinifera* varieties, the Labrusca varieties being used principally in New York and Ohio. A few *V. vinifera* and *V. labrusca* hybrids are also used in wine making. The European varieties, *V. vinifera*, are used in California, Australia, and South Africa to the practical exclusion of those of other species.

The variety to be chosen will depend upon the location, the type of wine to be made, soil conditions, climatic conditions, and other factors. In European wine regions, it is customary to plant the finer varieties on the higher slopes, as such locations usually favor high quality, although yields are low. On rich valley soils where production is high and quality correspondingly low, heavy bearing varieties of good to medium but not fine quality are usually planted, as the fine varieties are usually light bearers. Very hot regions are not favorable to high quality, although very large crops may be obtained. By experience European vintners have found, for example, that the Pinot Noir variety grown in Champagne and Burgundy is excellent for preparing the famous wines of those districts. In the Rheingau of Germany the Riesling varieties have been found best for the fine white wines of that district. In the hot Fresno district of California the Muscat is a favorite variety for use in making fortified sweet wine. In the eastern United States and Middle West Vinifera varieties are winterkilled; therefore hardy Labrusca varieties such as Catawba and Concord are grown. In French North Africa, where heavy blending wines are produced, the Carignane, a red variety of medium quality, is a favorite.

A. J. Winkler of the Viticulture Division of the University of California makes the following recommendations of dry wine varieties for California: Space will not permit a description of each variety.[1]

The following red wine varieties are recommended by Winkler for the interior valleys; Barbera, Carignane, Gros Mansenc, Mataro (in foothills), Saint Macaire, and Valdepeñas. For the same region he recommends the following white varieties; Burger, Clairette Blanc, Marsanne, Palomino, Vernaccia Sarda, and West's White Prolific.

For the warmer coastal valleys he recommends the following red varieties; Aramon, Barbera, Carignane, Gros Mansenc, Mataro, Petite Sirah, Refosco, Tannat, Valdepeñas, and Zinfandel; and the following white varieties; Burger, Green Hungarian, Marsanne, Palomino, Sauvignon Vert, and Semillon.

For the moderately warm coastal valleys with climate similar to that of Livermore, San Jose, and Ukiah are recommended the following red wine varieties; Aramon, Barbera, Cabernet Sauvignon, Carignane, Charbono, Mataro, Mondeuse, Petite Sirah, Refosco, Tannat, and Zinfandel; and the following white varieties; Burger, Franken Riesling, Grey Riesling, Muscat du Bordelais, Sauvignon Blanc, Sauvignon Vert, and Semillon.

For the cooler coastal locations the following red varieties are recommended; Beclan, Cabernet Sauvignon, Charbono, Mondeuse, Petite Sirah, Pinot Noir, Verdot, and Zinfandel; and the following white varieties; Chasselas Dore, Franken Riesling, Grey Riesling, Kleinberger, Johannisberger Riesling, Pinot Chardonnay, and Gewürz Traminer.

For very cool California regions the following white varieties are recommended; Chasselas Dore, Franken Riesling, Gewürz Traminer, Johannisberger Riesling, and Pinot Chardonnay.

For the making of Sherry the Palomino and Pedro Jimenez, also called Pedro Ximenez, the leading Sherry varieties of Spain are considered best. However, in California white shipping varieties, particularly Malaga, Tokay, and Thompson Seedless are generally used for this wine. In California the Carignane, Zinfandel, Alicante Bouschet, Mission, and occasionally Petite Sirah are the varieties commonly used for Port.

The Aleatico, a red Muscat variety, is popular in Italy for making a sweet wine.

In the eastern United States the following varieties have been used for wine: the Concord, a well-known black table and juice grape, used for red wines; the Catawba, a pink grape of spicy flavor used for white to pink wines; the Norton, a good red wine variety; the Delaware, a famous grape

[1] See Winkler, A. J., Grape varieties for dry wines, *Wines and Vines*, May, 1936, pp. 6–8, 22.

used for white wines, and the white varieties, Brighton, Diamond, Iowa, Missouri Riesling, Salem, Noah, and Diana. In the South the Scuppernong, a native grape is popular for wine making. It is green in color and of very pronounced flavor and aroma. In general, the eastern and Southern varieties are of much more pronounced flavor and aroma than the Vinifera varieties grown in Europe and California. It has long been the writer's belief that many American consumers of the Middle West, East, and South would prefer wines containing a recognizable "eastern grape" flavor. This could be attained by blending the eastern wines with those of California. He also believes that the California Muscat could be used much more extensively than at present to impart flavor and aroma. It is the only commonly grown Vinifera variety of strong flavor available at present in quantity in California for wine making. In a dry wine its flavor and aroma are very much subdued; some sugar appears to be necessary to "bring out" its characteristic flavor.

As the different types of wines are discussed, more will be said concerning varieties of grapes.

Maturity.—Grapes for wine making, insofar as possible, should be picked at the optimum maturity for the type of wine to be produced. The most desirable degree of maturity, as judged by sugar content, color, and flavor differs somewhat according to the type of wine to be made. Thus for dry wines the total soluble solids content as judged by Brix or Balling hydrometer inserted in a sample of the juice should be 20 to 22° Brix (Balling). For a heavy, red dry wine it may be 22 to 24° Balling. For wines of true Sauterne type the Balling degree may be 25 to 30° Brix, or even higher. For fortified dry wines (dry sherry) the Brix degree desired is 22 to 24°. For Muscatel, Angelica, and Port grapes testing 23 to 28° Brix are preferred, although often used at lower sugar content.

Addition of Sugar.—In some regions grapes do not attain so high a soluble solids content as mentioned above. This is particularly true in the eastern United States, Switzerland, the Champagne district of France, and the Rhine wine district of Germany. In such cases sugar may be added. In most countries this must be done under government permit and supervision. In the United States the amount that may be added is limited to 10 per cent, and it cannot be used either in the United States or other countries for "stretching," *i.e.*, making sugar wines by addition of water and sugar. The French designate such practice *chaptalisation*. For home consumption *piquette* is permitted in France; it may be made by adding water and sugar to the pomace (press cake) and fermenting.

In California the addition of water is sometimes necessary owing to excessively high sugar content of the grapes; very rarely, if ever, is added

sugar needed. California regulations prohibit the addition of sugar other than that of the grape, added as must or as concentrated must.

Pickling and Transportation.—Grapes for wine making should be picked with great care. Moldy and vinegar-soured bunches should be discarded. Boxes and buckets should be scrupulously clean.

In European countries the grapes are usually picked into baskets. For fine wines, often the individual berries are selected, or the bunches are trimmed by hand with small scissors as they are picked. This is true of the Rheingau, Champagne, and Sauterne districts. This practice is too costly for use in America.

Grapes should be delivered to the winery cool. Hence, it is customary in many vineyards to allow the boxes or baskets of grapes to stand overnight in the open to cool before delivery early the next morning. On the other hand in cold weather the attempt may be made to let the grapes become as warm as possible before delivery to the winery.

In transportation greatest care should be used to deliver the grapes within a few hours after picking and without deterioration in transit. The practice of dumping the grapes into large trucks or Gondola railroad cars holding several tons is to be deplored, because the grapes become crushed in transit and often partially vinegar sour or moldy. Fine or even good wines cannot be made from such raw material.

The grapes should be delivered in boxes or baskets and in fresh, whole, sound condition. For that reason the winery should be near the vineyards. If grapes must be transported long distances, they should be refrigerated, just as in shipment for table use.

Crushing and Stemming.—The classical method of crushing of former years in southern Europe was with the feet; a method still in use in some isolated localities. Fortunately, most of the wines of commerce are now made from grapes crushed by machinery.

The usual crusher consists of fluted bronze or steel rollers that revolve toward each other below a hopper. They are set at such distance that the flesh of the grapes is crushed, but the seeds left uninjured.

Below the crusher is a horizontal copper or steel cylinder, the lower half of which is perforated with holes about ¾ in. in diameter. Rapidly revolving metal paddles force the grapes through the openings into a concrete, or wooden sump beneath and "kick out" the stems through the open end of the stemmer.

In the Garolla-type crusher and stemmer crushing rolls are not used. The grapes are separated from the stems and crushed by revolving paddles in a horizontal, revolving metal cylinder. This machine is effective and efficient, giving a high yield of crushed grapes and good separation of the stems.

The crushed grapes in California are pumped by a special plunger and ball valve pump of wide diameter through a large pipe, usually of iron or copper, to the fermenting vats.

For making white wines often the stems are not separated, the mixed stems and crushed grapes being placed directly into the basket of the press or into press cloths.

Metals and Wines.—Must and wine attack certain metals severely and in most cases even very low concentrations of dissolved metals adversely affect the quality and stability of the wine. Extensive experiments made independently by Searle of the International Nickel Company and Mrak of this University show that steel, iron, copper, brass, zinc, tin, and aluminum are particularly undesirable. Traces of dissolved iron, 5 to 20 p.p.m., usually cause clouding of white wines and often precipitation of the color of red wines. Tin is equally objectionable. Zinc is very soluble and may dissolve in sufficient amount to make the wine toxic. Copper is less objectionable than iron, tin, and zinc, but steam coils used in cooking sherry often impart sufficient copper to the wine to make it unstable and of poor flavor. Metals in solution often catalyze objectionable changes in flavor. Brass is very soluble in wine. Nickel is attacked by must and wine but its alloys, as well as silver, stainless steels, and certain bronzes are extremely resistant to corrosion by must and wine. Crushers, filters, pumps, and metal pipes should be made of such alloys in order to reduce metallic contamination to a minimum.

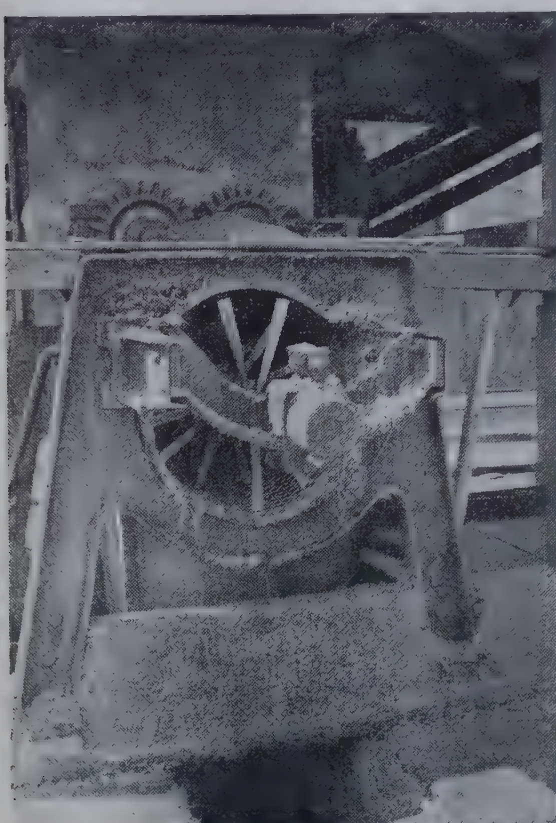
FIG. 102.—Grape crusher and stemmer.

Often rubber hose, wooden flumes, hard-rubber pipes, or glass-lined pipes may be used for moving must and wine in the winery.

Pressing.—In Chap. XV presses are discussed and described. In California the basket press is used for pressing fresh grapes for white wine and fermented grapes for red dry wine. In the eastern United States the rack and cloth, apple-juice type of press is often used. Continuous screw presses are used to a limited extent for pressing pomace in wine making, but as such presses yield a very cloudy press wine, they are considered less desirable than the basket press.

In the pressing of pomace from the fermentation of grapes for sweet wine continuous screw presses are used. Although the resulting press wine is very cloudy, this is not a serious fault since it is used for distilling for brandy needed in fortification.

Nature of Alcoholic Fermentation.—The evolution of bubbles of carbon dioxide, disappearance of sugar, and formation of alcohol, acids, and other substances constitute the phenomena of fermentation. These changes are brought about by the true wine yeast, *Saccharomyces ellipsoideus.* Other yeasts and bacteria are present and often participate in the fermentation. Practically, all of these either spoil the wine or injure its quality in proportion to the extent of their activity. There are a few exceptions; certain bacteria and wild yeasts under some conditions exert a beneficial effect. In most instances successful wine making depends upon proper control of fermentation; in other words the prevention of wild yeast and bacterial activity and promotion of that of the true wine yeast. For brief descriptions of the organisms involved see Chap I.

Space does not permit a detailed discussion of the theories of alcoholic fermentation. Some attention is given to this subject in the section on zymase in Chap. XXXIV. The so-called Neuberg theory is one that appears to explain the observed phenomena fairly satisfactorily, and will be outlined briefly.

As stated in Chap. XXXIV the first stage of alcoholic fermentation probably involves formation of hexose phosphates, resulting in activation of the hexose sugars, dextrose, and levulose present in the must. Harden and Young favor this theory.

According to the Neuberg theory the activated hexose sugar is next broken up into methylglyoxal by splitting of the six carbon sugar to two molecules of the three carbon aldehyde. Water is also lost by the sugar. Next, two molecules of the methylglyoxal react in the presence of water to give glycerol and pyruvic acid. Some of the latter is decomposed by carboxylase of the yeast to carbon dioxide and acetaldehyde. The latter and methylglyoxal then, by a Cannizzaro reaction, form ethyl alcohol and pyruvic acid. The sequence of reactions is repeated continuously resulting in evolution of carbon dioxide and formation of ethyl alcohol.

In terms of chemical reactions the foregoing transformations may be stated thus:

1. $C_6H_{12}O_6 + H_3PO_4 \rightarrow$

$$\overbrace{\text{CHOH—CHOH—CHOH—CHOH—CH}}^{\text{O}}\text{—CH}_2(\text{H}_2\text{PO}_4) + \text{H}_2\text{O}$$

Hexose phosphate

$$\overbrace{\text{CHOH—CHOH—CHOH—CHOH—CH}}^{\text{O}}\text{—CH}_2(\text{H}_2\text{PO}_4)$$

2. $CHOH—CHOH—CHOH—CHOH—CH—CH_2(H_2PO_4)$
$\rightarrow H_3PO_4 + \underset{\text{Methylglyoxal}}{2CH_3C{:}OCH{:}O} + 2H_2O$
3. $CH_3C{:}OCH{:}O + CH_3C{:}OCH{:}O + 2H_2O$
$\rightarrow \underset{\text{Glycerin}}{CH_2OH\ CHOH\ CH\ OH} + \underset{\text{Pyruvic acid}}{CH_3C{:}OCOOH}$
4. $CH_3C{:}OCOOH \rightarrow CO_2 + \underset{\text{Acetaldehyde}}{CH_3CH{:}O}$
5. $CH_3CH{:}O + CH_3C{:}OCH{:}O + H_2O$
$\rightarrow \underset{\text{Pyruvic acid}}{CH_3C{:}OCOOH} + \underset{\text{Ethyl alcohol}}{CH_3CH_2OH}$

Briefly, some of the evidence for existence of the foregoing is as follows: (1) There is always some acetaldehyde present in fermented liquids; (2) in the presence of sodium sulfite a large yield of the aldehyde-sulfur dioxide compound is obtained; (3) in an alkaline medium much glycerin accumulates, a fact made use of industrially during the World War to obtain glycerin for use in preparing nitroglycerin, a high explosive; (4) some pyruvic acid can be recovered.

Some acetic acid is formed in normal yeast fermentation, possibly by the reaction

$$\underset{\text{Acetaldehyde}}{CH_3CH{:}O} + \underset{\text{Acetaldehyde}}{CH_3CH{:}O} + H_2O \rightarrow \underset{\text{Ethyl alcohol}}{CH_3CH_2OH} + \underset{\text{Acetic acid}}{CH_3COOH}$$

There are also formed small amounts of lactic acid, $CH_3CHOHCOOH$; succinic acid, $COOHCH_2CH_2COOH$; and propionic acid. In addition to ethyl alcohol, fermented liquids contain small amounts of some of the higher alcohols, notably normal propyl alcohol, $CH_3CH_2CH_2OH$; isopropyl alcohol, $CH_3CHOHCH_3$; normal butyl alcohol, CH_3CH_2-CH_2CH_2OH; isobutyl alcohol, $(CH_3)_2CHCH_2OH$; normal primary amyl alcohol, $CH_3(CH_2)_3CH_2OH$; and isoamyl alcohol, $(CH_3)_2CHCH_2CH_2OH$. The amyl alcohols are probably formed not directly from sugars but from amino acids.

During aging of wine or brandy the various alcohols and esters react to some extent to give esters upon which much of the flavor and bouquet of the wine depend.

If all of the dextrose and levulose of the must were converted into alcohol and carbon dioxide, the reaction would be $C_6H_{12}O_6 \rightarrow 2CO_2 + 2C_2H_5OH$; or from 100 grams of hexose sugar would be obtained 51.1 grams of alcohol and 48.9 grams of carbon dioxide. Pasteur on the basis of careful analyses decided that wine yeast gave 48.4 grams of alcohol, 46.6 grams of carbon dioxide, 3.2 grams of glycerin, and 0.6 gram of succinic acid. The yeast used 1.2 grams of the sugar for cell structure and other purposes. We now know that a number of other compounds are formed in alcoholic fermentation as previously mentioned.

Wines usually contain 0.5 to 1.0 gram of glycerin per 100 cc.; this substance adds materially to the flavor and "body" of the wine. In a new, sound dry wine there is from 0.03 to about 0.06 gram of volatile acid, chiefly acetic, per 100 cc.

From these facts it can be seen that wine contains a complex mixture of compounds, some present in the grape and others formed during fermentation.

Practical Rule for Calculating Alcohol Yield.—Alcohol content of wine is usually expressed as volume per cent, *i.e.*, cubic centimeters of alcohol per 100 cc. of wine; 1 cc. of alcohol weighs approximately 0.8 gram. Therefore, volume per cent is considerably greater than per cent by weight. By experience it has been found that Balling degree of the must $\times$ 0.57 gives the approximate alcohol content of the dry wine made from any given must. Thus a grape must of 22° Balling should give a dry wine of about $22 \times .57 = 12.5$ volume per cent of alcohol.

Conditions Favorable to Wine Yeast.—The natural acids of grapes discourage the growth of acid-intolerant organisms and have little or no retarding effect on wine yeast. Often, in order to promote normal, sound fermentation, citric, tartaric citric, or malic acids are added to musts low in acidity. Acetic acid formed by bacteria not only spoils the flavor of wine but inhibits growth of the wine yeast.

Yeasts require oxygen for optimum growth and activity. If aeration is excessive, alcoholic fermentation may become inefficient, and if insufficient aeration is given, fermentation may be incomplete. Often, toward the end of fermentation, the yeast becomes inactive and fermentation ceases before completion. Aeration at this point will often revive the fermentation.

Temperature during fermentation is of very great importance. Maximum alcohol production in tests by Hohl of this laboratory has been secured at temperatures below 75°F. Fermentation usually ceases at about 100°F. with accompanying death of the yeast. Most wine yeasts ferment very slowly at or below 50°F.

The presence of large numbers of wild yeasts retards true wine yeast development because they compete with it for yeast food, particularly phosphates and nitrogenous substances. For this, as well as other reasons, such organisms should be inhibited by addition of sulfur dioxide or in some other manner.

Wine yeasts differ considerably in respect to their alcohol-forming power, rates of fermentation, temperature relationships, and response to aeration.

Selective Action of Sulfur Dioxide on Microorganisms.—It is a well recognized fact that sulfur dioxide or rather its hydrated form sulfurous

acid, H_2SO_3, exerts a selective action on the various yeasts, bacteria, and molds present on grapes and in must. The writer found, in experiments made with Californian musts and microorganisms in 1911 to 1915, that 100 p.p.m. of sulfur dioxide added to fresh must prevented for several days or longer the growth of all the molds, wild yeasts, and bacteria present on the grapes used, or isolated from other grapes and added in pure culture, but permitted growth of the true wine yeast. Hence, when to musts containing several million cells of wild yeast and vinegar bacteria and a few hundred true wine yeast cells was added 100 to 150 p.p.m. of sulfur dioxide there was a decrease in the number of wild yeasts and bacteria and rapid increase of the true wine yeast followed by normal, sound alcoholic fermentation.

Sulfurous acid also has proved to be of great value in preventing growth of spoilage bacteria during aging of wines. The concentration required is only 75 p.p.m. in most cases, as the lactobacilli responsible for such spoilage are very sensitive to sulfur dioxide.

Adding Sulfur Dioxide or Potassium Metabisulfite.—Sulfur dioxide is usually purchased in liquefied form in steel cylinders. In using it in this form the cylinder is placed on platform scales and weighed. The outlet valve is connected by hose to a perforated copper, stainless-steel, or hard-rubber pipe inserted into the vat of must or crushed grapes. The calculated weight of sulfur dioxide is added slowly with stirring. Or the gas is passed into cold water slowly to give a solution containing 5 to 6 per cent of sulfur dioxide. This is titrated with N/10 iodine solution before use.

Potassium metabisulfite, the anhydride of potassium bisulfite, is a popular source of sulfur dioxide in wine making, as it is convenient to use. It is dissolved in water to give a solution usually containing ½ lb. of the metabisulfite per gallon. It is added as the vat is filled with crushed grapes. Potassium metabisulfite contains, theoretically, nearly 58 per cent of sulfur dioxide. Since there is loss from volatilization and oxidation, it is customary to assume that potassium metabisulfite contains for practical purposes about 50 per cent of sulfur dioxide. In the must sulfur dioxide is liberated by reaction between the fixed acids and the metabisulfite.

If the grapes used are sound the usual amount of sulfur dioxide required for satisfactory control of microorganisms is about 4 oz. per ton, or of potassium metabisulfite, about 8 oz. per ton of crushed grapes. If the grapes are in poor condition, the dose should be increased to 6 to 8 oz. of sulfur dioxide or 12 to 16 oz. of metabisulfite per ton. An addition of 4 oz. of sulfur dioxide or 8 oz. of metabisulfite per ton is equivalent to about 120 p.p.m. of sulfur dioxide or about 120 mg. per 1,000 grams.

Sodium bisulfite, $NaHSO_3$, is much lower in cost than potassium metabisulfite and equally satisfactory as a source of sulfur dioxide. It is used rather commonly in lieu of potassium metabisulfite.

Control of Temperature.—Excessively high temperatures during fermentation encourage the growth of wine-disease bacteria. At high temperatures, moreover, the yeast causes reactions that are unfavorable to the quality of the wine. A wine fermented at temperatures of about 70°F. is smoother, fresher, and of more desirable bouquet than one fermented at 90 to 95°. The latter, if fermented on the skins, is apt to have more color, tannin, and body, owing to the greater solvent action on those substances at the higher temperature.

It is generally accepted by oenologists that more bouquet and aroma are formed in a wine made by a long slow fermentation at low temperatures than by a short rapid fermentation at higher temperatures. In cool fermentations the yeast apparently produces more esters and other aromatic bodies. This is also true for other fermented fruit products, *e.g.*, cider. Recently Italian oenologists have introduced a method of fermentation in which the must is cooled almost to its congealing point and then allowed to gradually warm up and ferment. This process, it is claimed, results in a superior wine.

A great deal of heat is generated during alcoholic fermentation, and a rise in temperature of the must follows unless this heat is dissipated. The heat evolved from 180 grams of sugar consumed in the reaction $C_6H_{12}O_6 = 2C_2H_5OH + 2CO_2$ has been calculated to be between 32 and 33 Cal. However, a measurement in fermenting wine by A. Bouffard gave 23.5 Cal. On this basis a must containing 22 per cent sugar would rise 90°F. in temperature if all the heat developed by fermentation were prevented from escaping. It would reach 100° and stick, while it still contained 12 per cent of sugar, if its initial temperature were 60°.

The temperature to which the fermenting grapes or must will rise is determined by their temperature when crushed, plus the rise in temperature owing to the heat generated by fermentation, and minus that lost during fermentation by radiation and conduction. The warmer the grapes and the more sugar they contain, therefore, the higher the temperature will rise. The smaller the fermenting mass, the cooler the air, the greater the heat radiation from the vats, and the slower the fermentation, the less the temperature will rise. Cooling the grapes or must, fermenting in vats with a large radiating surface per unit volume, cooling the air in contact with the fermenting vats, and more particularly cooling the fermenting must itself are the means by which dangerously high temperatures during fermentation may be prevented. In the cool coastal regions the use of small fermentation vats and gathering the grapes early in the morning, or allowing those gathered in the hot part

of the day to cool in the night air before crushing, are often sufficient to avoid too high a temperature during fermentation. Where large fermenting vats 3,000 to 10,000 gal. in capacity are used, and especially in the hot interior valleys, it is necessary to cool the fermenting must artificially. Cooling the must before fermentation has also been practiced, as mentioned on page 645.

The heat lost by radiation in ordinary open fermentation vats not exceeding 3,000 gal. in capacity is about 50 per cent of that generated by fermentation, except in the hottest weather. In larger vats up to 10,000 gal. in capacity and in very hot weather, the loss may be no more than 33 per cent. The amount of cooling necessary has been calculated as follows by F. T. Bioletti:

Let

S = Balling degree of must (approximate sugar content).
T = temperature of contents of vat.
M = maximum temperature desired.
C = number of degrees Fahrenheit necessary to remove by cooling.

Then

$$C = 1.17S + T - M$$

Examples:

$$S = 24, \qquad T = 80°\text{F.}, \qquad M = 92°\text{F.}$$

Then

$$C = (1.17 \times 24) + 80 - 92 = 16°\text{F.}$$

That is, in this case, every gallon in the vat has to be cooled to 16° below the temperature at the beginning of cooling in order to maintain a maximum of not over 92°. It is sometimes best to wait until the must in the fermenting vat reaches a temperature a few degrees below the desired maximum before cooling. It must also be remembered that fermentation and production of heat continue during cooling. The addition of ice to the fermenting vat to lower the temperature has been used with musts high in sugar content, but the use of various forms of tubular refrigerators is more satisfactory. Various types of refrigerators are available, but they are essentially the same in principle. Some consist of an inner tube or coil through which the wine is pumped and which is cooled by direct expansion of the refrigerant or by a cold liquid circulated in an outside jacket. In some the wine flows in the outside jacket and the cooling medium in the inner tube. This cooling liquid may be water or refrigerated brine. If well water is used, it is generally necessary to cool the fermenting must continuously during the height of fermen-

tation. An efficient variation of the tubular type of heat interchangers is one in which banks of coils through which wine is pumped are either cooled by sprays or streams of ice water or are packed in ice. This type of cooler can be used where ice is available locally and the winery lacks other refrigerating machinery. Another common but less efficient cooling device consists of a large coil immersed in the vat of crushed grapes; water or refrigerated brine is circulated through the coils. Still another cooler consists of metal coils immersed in a sump into which the wine to be cooled is pumped; cold brine is pumped through the coils. The tubes or coils with which the wine is in contact should be made of corrosion-resistant metal such as stainless steel, or nickel and never iron, tin, or steel. There is evidence that copper also is not desirable.

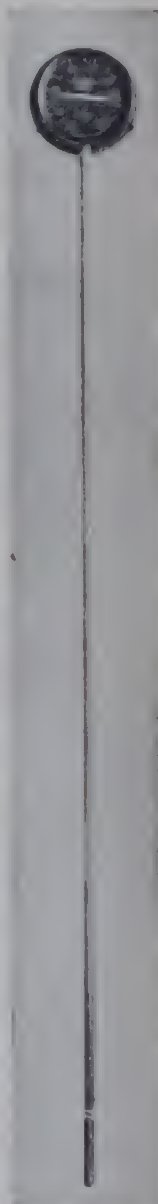

Fig. 103.—Long-stem thermometer for testing temperature of fermenting must.

A careful check of the temperatures reached in the fermenting vats should be made at frequent intervals to avoid stuck tanks. The rise of temperature is greater in fermenting crushed red grapes than it is in white musts, as less heat is lost from the surface. The pomace has a tendency to rise to the top and form a semidry "cap" in which the temperature becomes excessive, even when the must below keeps comparatively cool. Pumping over, an operation resorted to very frequently for stimulating a dilatory fermentation, does not produce appreciable cooling; in fact the stimulated fermentation may increase the temperature. Toward the end of fermentation a high temperature entails also a loss of alcohol and the development of a flat taste. Cold weather during the late fall or early winter may result in sticking because of the lowering of the temperature. In this case it may be necessary to warm the wine in order to complete the fermentation. This may be done by using a tubular heat interchanger such as a pasteurizer or by using similar means. The thermometer shown in Fig. 103 is useful for taking temperatures in wine vats.

Refrigerating the wine to a suitable degree after fermentation is complete promotes rapid clarification by the precipitation and deposition of salts, microorganisms, and the other solid matter which otherwise often form a persistent cloudiness. A suitable rise of temperature after the wine has been cleared by settling and racking hastens aging. When aging is complete, sufficient lowering of the temperature checks overaging and makes it possible to keep the wine until it is bottled.

Fermentation of Dry White Wine.—Several methods of fermentation of white musts are in common use. One of the more popular methods employed in California consists in placing the crushed grapes in open, circular redwood vats holding 1,000 to 10,000 gal. each. Sulfur dioxide or potassium metabisulfite is added to give a concentration of 100 to 150 p.p.m. of sulfur dioxide, and a starter of pure yeast is added. Fermentation is allowed to proceed for 24 to 48 hr. for the purpose of extracting some tannin from the skins and to disintegrate the grapes somewhat, thereby facilitating pressing and increasing the yield of must. Fermentation of the expressed must then proceeds to completion in oval tanks, puncheons, or redwood tanks. This method is used for Sauterne-type wines to a greater extent than for Rhine-wine-type wines. The principal fault of the method is its tendency to produce wines of dark-amber to brown color.

A better method of fermenting dry white wines consists in crushing the grapes without removing the stems as the latter facilitate pressing; adding 100 to 150 p.p.m. of sulfur dioxide; pressing; adding a yeast starter; and fermenting in covered tanks or puncheons.

It is considered good practice to rid the must of its coarse suspended pulp before fermentation. Therefore, in some wineries to the freshly expressed juice is added 150 to 200 p.p.m. of sulfur dioxide, and the juice is allowed to settle for 24 to 36 hr. It is then racked (drawn off), inoculated with pure yeast, and fermented in covered tanks. In some references the process of settling is spoken of as "defecation"; the term "settling" appears to be preferable. Our investigations show that enzymes are active during settling; and the clearing of the must is hastened and clearness improved by adding a pectic enzyme such as Pectinol at the rate of about 1:5,000. The sulfur dioxide mentioned above prevents fermentation during settling.

For reasons previously given the temperature during fermentation should not be permitted to exceed 80°F. for white wines.

The rate of fermentation is followed by taking the Balling degree one or more times a day. The temperature should also be taken at least twice a day. The readings may be recorded in chalk on the wall of the vat or tank.

Since alcohol formed during fermentation is of lower specific gravity than water and since it exceeds in amount the unfermentable soluble solids, the Balling degree eventually decreases to less than 0° Balling; often decreasing to −2.0° Balling. Taste is a better guide than the hydrometer in determining when fermentation is complete; but also it should be confirmed by chemical analysis.

A dry white wine should ferment until eventually it contains less than 0.20 gram of sugar per 100 cc. If at any time fermentation ceases before

this point is reached, the cause should be determined and steps taken to force fermentation to completion. If the must contains too much sugar to be fermented completely, the addition of water may be necessary; if the temperature of the must drops below 60°F., it must be warmed, or if oxygen is required by the yeast, as is often the case, the wine must be aerated by pumping over, or by pumping air through, it.

When fermentation becomes slow, usually after 5 to 6 days, a fermentation bung should be placed on the tank or puncheon. This is often merely a bottle of water to the bottom of which is inserted a bent glass or metal tube which also passes through the bung. The carbon dioxide escapes through the water against a slight pressure which maintains an atmosphere of carbon dioxide under slight pressure in the tank. This in turn prevents the growth of vinegar bacteria and mycoderma yeasts until fermentation is complete.

When fermentation is complete, the tank must be filled completely with wine of similar quality and sealed by driving the bung in tightly in order to exclude air.

Pure Yeast Starters.—Fermentations are more uniform, and the average quality of the wines is better if starters of selected strains of pure yeast are used to initiate fermentation of crushed grapes and must. The oenological stations of Germany, France, and Italy have studied many different strains of true wine yeast, *Saccharomyces ellipsoideus*, and supply the best to the industry. Such cultures may be obtained from the Geisenheim Institute of Viticulture in Germany, or the various French oenological stations, the American Type Collection at the John McCormick Institute for Infectious Diseases, 629 South Wood Street, Chicago, Ill., and from various commercial laboratories whose addresses may be secured from the Fruit Products Division of this University or from the Division of Chemistry of the New York Agriculture Experiment Station at Geneva, N. Y.

The culture is purchased, usually as an agar slant in a test tube or bottle. Sterilized grape juice is added at the winery in such manner as not to contaminate the culture. When in fermentation, this tube or bottle of pure culture is poured into a cotton-plugged gallon jug of sterile juice. When this juice is in fermentation, it is added to about 10 gal. of sterilized, cool juice in a barrel or open wooden tub covered with cloth. When the 10 gal. is in fermentation, it is added to 50 to 100 gal. of must sterilized by steam coil and cooled or rendered practically sterile by addition of 150 p.p.m. of sulfur dioxide. The latter is usually more convenient and is very effective. In like manner the culture may be increased to any desired volume.

When in full fermentation, from 50 to 75 per cent of the contents of the yeast tub is used for inoculating vats or tanks of crushed grapes or

must in the winery, and the liquid so removed is replaced by fresh must sterilized by heat or by sulfur dioxide. Usually 2 to 3 per cent of starter by volume is used as an inoculation.

A very convenient means of sterilizing the must is to pass it through an ordinary continuous wine pasteurizer, which sterilizes the juice by heat and cools it to room temperature continuously.

It has been found that the following strains of wine yeast give excellent results in California: Champagne Ay yeast and so-called U. C. Burgundy yeast, both from P. Pacottet of France, and Tokay yeast, imported a number of years ago from Europe by Fruit Industries, Ltd. The first two yeasts are of the granular or agglomerating type and settle rapidly after fermentation is complete. They are useful on this account for Champagne making also. The Tokay yeast is a fine grained or pulverulent type of yeast; but it is a strong fermenter.

Red Wine Fermentation.—The crushed grapes are pumped from the crushing sump to the fermenters through a pipe line of large diameter by means of a plunger pump equipped with heavy metal ball valves which permit free passage of the crushed grapes without clogging the pump.

It is advisable to add from 2 to 6 oz. of sulfur dioxide per ton of grapes or twice this amount of metabisulfite during or immediately after crushing, distributing it equally throughout the crushed grapes in the vat. If the crusher, pump, and must line are of materials not corroded by sulfited juice, the sulfur dioxide in solution may be added at the crushing sump; otherwise, it must be added to the crushed grapes as they fall into the vat or shortly thereafter (see section on sulfur dioxide).

The metabisulfite should be dissolved in water, a convenient concentration being 8 oz. to each gallon of water. For fresh grapes relatively free from mold 6 to 8 oz. of metabisulfite per ton is sufficient. For moldy grapes or those that have become partially crushed and soured in transit, 12 to 16 oz. per ton is required.

In all cases the crushed grapes must be thoroughly mixed by punching or pumping over to insure that the sulfur dioxide is evenly distributed.

The addition of either sulfur dioxide or metabisulfite destroys or inactivates wild yeasts, bacteria, and molds, but the true wine yeasts are not materially injured by the amounts of sulfur dioxide or metabisulfite recommended.

After adding the sulfur dioxide or metabisulfite, there should be added 2 to 5 per cent by volume of actively fermenting yeast starter, *i.e.*, 4 to 10 gal. of strongly fermenting must to each ton of crushed grapes or to approximately each 200 gal.

Two gallons of yeast is sufficient in hot weather; 8 is better in cold weather. If the grapes are warm, the yeast should be added within 3 hr. after sulfiting. The yeast and crushed grapes should be well mixed

by punching, or better by pumping over. Directions for preparing the yeast have been given in a previous section.

If the grapes are sound and free from mold or vinegar souring at the time of crushing, some of the *fermenting* must of a vat previously started with pure yeast may be used to inoculate other vats of crushed grapes, and these in turn used to inoculate still other vats.

The Balling (Brix) degree and the temperature of the must should be tested as soon as the vat is filled. As soon as fermentation commences, these tests should be made again and repeated at least twice every 24 hr. while the grapes are still in the vat. A record of these tests, showing the data and hour made, should be kept in a book or on filing cards and also on the vats where they can be referred to easily. These records form a valuable guide for future care of the wine. They show how the fermentation is progressing, show when to carry out the various operations, and also indicate whether the fermentation has been abnormal and therefore requires special treatment. Long-stemmed copper-sheathed vapor-filled dial-type indicating thermometers are now available for winery use. They are very convenient and useful (see Fig. 103).

In interpreting the Balling readings, the temperature correction should be borne in mind. As an approximate correction add 0.3° Balling for each 10°F. above the temperature for which the particular hydrometer was standardized and subtract 0.3° Balling for each 10°F. below this temperature. This amounts to a correction of about 1° Balling for each 30°F. above or below the standard temperature (usually 60 or 65°F.).

The sample for testing should be taken with a wine thief (glass tube made for the purpose) or with a short piece of rubber hose from a level well below the cap, since fermentation in the cap is more rapid and a test made upon juice expressed from it would be misleading.

As soon as fermentation is evident, the contents of the vat should be well stirred by punching or pumping over at least twice a day. This is to equalize the temperature, to promote extraction of color and tannin, and to aerate the must. Aeration should be moderate or omitted during the violent fermentation. If the beginning or ending of fermentation is sluggish, aeration should be more severe to invigorate the yeast. It is best to keep the cap of floating skins and stems as fully submerged as possible in order to discourage vinegar souring.

The best red wines are made when the temperature does not rise above 85°F. Temperatures above 90° notably impair the quality. The temperature of the wine should be taken just below the cap, for at this level the wine temperature is highest owing to the insulating effect of the cap. However, the highest temperature in the vat is usually in the cap, about half way down. The temperature should be taken with a long-stemmed thermometer whose bulb is immersed in the vat while

reading. Temperatures read on thermometers attached to hydrometers or on small thermometers pulled out of the vat to be read may be too low by as much as 10°F.

Where cooling devices are available, they should be used as soon as, or a little before, the temperature reaches 85°F. The amount of cooling necessary will depend on the amount of sugar left, the size of the vats, and the temperature of the air (see also the discussion on cooling, page 645). The cooling is generally done by drawing the free-run wine off the pomace through a screen into a concrete sump. From this sump the wine is pumped through tubular refrigerators or through coils packed in ice (or cooled with running water) as mentioned previously. The wine should be cooled to about 70 to 80°, according to the amount of sugar remaining, and then pumped back over the pomace into the fermenting vat.

The time for separating the wine from the pomace by drawing off and pressing is determined by the thoroughness of the extraction of tannin and color desired by the wine maker. The amount of sugar left has little to do with it, as the fermentation will finish as well after as before drawing off. The alcohol formed during fermentation, together with the heat, the agitation, and the mechanical disintegration of the pulp by fermentation, extracts the color and tannin from the skins. The maximum color is usually obtained after about 72 hr. of active fermentation on the skins. In cool fermentations it may require 4 or 5 days. Sufficient tannin is usually extracted at the same time, but with a few varieties of grapes, or if very astringent wines are desired, the grapes may be left 1 or 2 days longer in the vat. In properly conducted fermentations, the time from filling the vats to drawing off the wine will normally range from 3 to 5 days. Usually the wine tests 0 to 4° Balling at this time. The free-run wine should be kept separate from that obtained by pressing the pomace left in the vat. The free run is less harsh, easier to age, and yields a wine of better quality than the press wine. The pomace (skins, seeds, and small pieces of stems) is shoveled from the vat to a conveyer or into a car for transportation to the press; or with a basket press, it may be shoveled directly into the press basket on a truck. A basket-type press is considered by many wine makers preferable to a continuous press for this purpose because it expresses less of the finely divided pulp from the grapes. The continuous press is naturally less costly to operate as it requires less labor. If the press wine is to be used for distillation for brandy or returned to a fresh vat of grapes, there is no objection to using a continuous press.

Fermentation destroys the mucilaginous or "gummy" condition of freshly crushed grapes and renders pressing easy and effective.

In many wineries the press wine is returned to a vat of freshly crushed grapes to act as a starter and to rid it of much of its suspended matter. This procedure also greatly reduces the total volume of press wine (a second-quality product) and correspondingly increases the yield of free-run wine. The practice is supported by some for these reasons and condemned by others because it tends to lower somewhat the average quality of the free-run wine.

In wineries that make sweet wine as well as dry, the pomace is usually mixed with water to reduce the final alcohol content to 6 or 7 per cent and is left in the vat to allow fermentation to run to completion, a period of not more than 2 days. The free-run "wash" is drawn off and the pomace is pressed; the two lots of liquids are then combined and sent to the still. Better practice is to leach the drained pomace with water before pressing in order to recover as much of the residual alcohol as possible.

In most wineries the pressed pomace is dumped in a large heap outside the winery and is later hauled away to a dump or spread thinly in a vineyard or orchard to be plowed under later. If applied too heavily to the soil, it may injure the vines or trees. It has very little fertilizing value but will improve the texture of heavy soils. Lime may be mixed with it to neutralize the acidity. In a later section the recovery of cream of tartar and tannin from waste pomace is discussed briefly. In California much of the pomace is dehydrated in rotary dryers and ground in a hammer mill to yield a stock food used in mixed feeds for dairy cows.

When the wine in the fermenting vat is drawn off, it nearly always contains a small amount of fermentable sugar. In order to complete the fermentation, the new wine is placed in closed storage tanks with fermentation bungs and maintained at a suitable temperature (70 to 80°F.).

Drawing off and pressing stimulate the yeast by aerating the wine. If this aeration is not sufficient and the wine still tastes sweet a week after being placed in storage casks, it should be well aerated by pumping over. This aeration should be repeated every 2 or 3 days until the fermentation is complete. In cold weather it may be necessary to warm the wine to 75 to 80°F. by use of a pasteurizer or other form of heater. In from 7 to 14 days after crushing of the grapes, all red wines should be completely dry (or free of fermentable sugar) if favorable conditions are maintained. Excessive aeration after secondary fermentation is complete should be avoided as it may endanger the quality of the wine by overoxidation or acetification. The storage vats should be as full as possible to avoid souring. As soon as fermentation is complete the tank should be filled completely and bunged. The bung should be loosened every few days to allow the gas to escape.

After fermentation ceases, the yeast and suspended particles of skins and pulp settle rapidly, forming a sediment known as the first or crude lees. During the settling period the tank or cask must be kept well filled and sealed.

Other Methods of Red Wine Fermentation.—At one time considerable red wine was made in California by the following procedure. To the crushed and stemmed grapes was added a small amount of sulfur dioxide, and they were then heated to about 130 to 140°F. by drawing off the must from the vat, heating it, and returning it to the vat until the contents attained the desired temperatures. After standing long enough to extract the desired color (1 to 3 hr.), the grapes were pressed, the juice was cooled, and fermented free of the skins. The pomace was mixed with water, fermented, and used for distillation. This procedure gives a wine that is smooth and which ages rapidly.

In the so-called Semichon method of fermentation, wine is added to the must to increase the alcohol content to above 5 per cent, the purpose being to prevent the growth of wild yeasts without the necessity of adding sulfur dioxide. In practice the method is nearly useless because lactic bacteria are not inhibited and may completely spoil the wine.

First Racking.—When the fermentation is complete, the new wine is drawn off (racked) from the lees to aid in clearing and to avoid extraction of undesirable flavors from the old yeast. A centrifugal separator has been used for removing suspended yeast and other solid particles immediately after fermentation. It shortens the settling period, but its general adoption is not advised until sufficient time has elapsed to prove its utility and desirability as a substitute for settling and racking. Much the same effect can be attained by a short settling period followed by racking and rough filtration through a coarse pulp filter or with a filter aid through a filter press, or clarification with a powerful clarifying agent such as bentonite (see filtration, page 657). The lees from the first racking are generally distilled for brandy in California; cream of tartar also can be recovered.

Storage and Racking.—After the secondary fermentation is complete and the wine is freed from yeast and other suspended material, it is stored in completely filled and sealed tanks. Since some wine is lost by evaporation during storage, vinegar souring may occur unless the tanks are kept full. They must be filled frequently during the first few weeks and less frequently later, owing to contraction on cooling. During storage also, racking is repeated at more or less regular intervals to aid in clearing. During racking the wine loses the carbon dioxide with which it is charged and absorbs oxygen necessary to aging. No oxidation and consequently little aging occurs as long as the wine is charged with carbon dioxide. It is customary to perform the first racking in December and early January

and the second in March or April. During storage, aging, with its improvement in flavor and bouquet and accompanying clearing of the wine, occurs. Dry wines usually require storing for at least 2 years to "age" before they are fit for consumption. During this aging a complex process of oxidation and esterification occurs and results in the formation of the desirable aroma and bouquet and loss of the raw flavor of new wine. Another vitally important change is separation of the excess cream of tartar. Alcohol formed during fermentation and the low temperature of the storage room combine to hasten its separation. However, after the first rapid deposition of cream of tartar, further separation is extremely slow and often requires several years for completion in usual cellar practice.

Refrigeration.—The solubility of cream of tartar and that of certain colloidal materials, such as certain proteins, gums, etc., are greatly decreased and the rate of separation correspondingly increased by lowering the temperature to near the freezing point of the wine. In recent years refrigeration has come into use in Europe for hastening these changes and has been very generally adopted in California.

Two systems are in use. In one of these the wine is pumped continuously through brine-cooled, or refrigerant-cooled coils until the temperature of the tank of dry wine (usually 20,000 to 30,000 gal.) is reduced to between 24 and 30°F. Later the wine is again cooled, several times if necessary, to maintain a temperature below 27°. The tank stands in the storage cellar. Fortified wines are cooled to much lower temperatures, usually to about 16 to 17°F. as their freezing point is lower.

In the second system the tanks are housed in a refrigerating room at 24 to 27°F. The wine is cooled as previously described and pumped cold into the tanks, in the cold room. This system is very costly, and it is an open question whether the added cost is justified. Sometimes refrigerated brine coils or direct expansion coils or plates are placed in the storage vat and cold brine circulated through these coils to cool the wine and to maintain a low temperature.

After several days, usually 15 to 20, the wine is filtered cold to remove the cream of tartar and other separated substances, spoken of loosely in the industry as "albumins." Sometimes a longer storage period is used.

A desirable modification of this procedure consists in rough filtration of the new wine, flash pasteurization at 175 to 180°F., and cooling at once to room temperature before refrigeration. Pasteurization coagulates considerable protein by heat and in this manner, probably, increases the stability of the wine. The wine is then cooled to 24 to 27°, stored a few days, and filtered cold as previously described.

This treatment removes practically all of the excess cream of tartar so that wine so treated does not deposit crystals of this salt in the cask

or bottle. However, the acidity may be so greatly reduced thereby that acidification with citric or tartaric acid is necessary. Citric is preferred.

Theory of Aging.—During aging, wine changes from a liquid of harsh, "raw" flavor and odor to one of mellow, "smooth" flavor and characteristic bouquet and aroma. Some of the disagreeable flavor of new wine is due to its "yeasty" flavor which with time disappears.

Some of the changes of aging are caused by oxidation of tannin, coloring matter, higher alcohols, and other compounds, and some are due to the formation of esters. The first effect of oxidation is to render the wine flat in flavor and bouquet. If further oxidation is arrested for a time, a pleasing flavor and bouquet develop. Oxygen of the air diffuses slowly through the wood of casks and tanks and brings about some oxidation. It is likely, however, that wine stored in very large tanks obtains most of the oxygen required for aging during the unintentional aeration given during racking, pumping over, filtering, and pasteurizing. F. de Castella of Australia states that, during the aging of wine under normal conditions, about 30 cc. of oxygen per liter is absorbed through the pores of the wood and about 5 to 6 cc. per liter with each racking; or possibly about 100 cc. during 2 years' storage with 4 rackings a year. This quantity is considered sufficient to induce the normal amount of oxidation required before bottling, according to de Castella.

However, the amount of oxygen required will vary greatly with the type of wine; a heavy, harsh, dry red wine requires much more oxygen than a light, white dry wine. Sherry requires many times as much oxygen as an Angelica or Muscatel. The presence of sulfur dioxide retards oxidation of the wine, as considerable oxygen is consumed in converting sulfurous to sulfuric acid.

After a wine is aerated or treated with oxygen, an increase in acetaldehyde occurs, followed by oxidative changes probably because of secondary oxidations caused by the aldehyde.

Some of the effects of oxidation are undesirable. White wines may become too dark in color or lose most of their delicate aroma, and red wines deposit their red color and become flat in flavor, if oxidation is too severe. Wines from moldy grapes contain an active oxidase that hastens oxidation of the tannins and coloring matter.

Esterification during aging accounts for much of the change in flavor and bouquet, as esters are very aromatic. Esterification is a combination of acids and alcohols as illustrated by the simple equation

$$\underset{\text{Ethyl alcohol}}{C_2H_5OH} + \underset{\text{Acetic acid}}{CH_3COOH} \rightarrow \underset{\text{Water}}{H_2O} + \underset{\text{Ethyl acetate}}{CH_3COOC_2H_5}$$

Many other esters are formed in the combination of higher alcohols with acetic, tartaric, and other acids. Ethyl acetate, ethyl isobutyrate, ethyl

succinate, amyl acetate, and traces of esters of higher acids have been found in aged wine.

Certain varieties of grapes of pronounced aroma, such as Concord, Catawba, Muscat, Semillon, and Sauvignon, impart their characteristic aroma to wines made from them. The predominant ester in Concord grapes was found by Power to be methylanthranylate.

In other words, the odor of aged wine is in part due to the "bouquet" formed by transformation by oxidation and esterification of the products of fermentation and in part due to the "aroma" of the grapes.

Artificial Aging.—This subject is more fully discussed by Joslyn (1934), Fain, and De Castella (see reference list at the end of the chapter). In brief, as at present applied to dry wines it consists in refrigeration, oxygenation, flash pasteurization, storage at 24 to 27°F., and cold filtration. This procedure is essentially that followed in the Monti process invented by Eudo Monti many years ago and used in the present Charmat process of France. The wine is aerated intermittently during cold storage in one system of rapid aging, is then warmed to, or above, room temperature, and is refrigerated intermittently to hasten aging. In another process the wine after pasteurization, refrigeration, and filtration is stored at a temperature above room temperature, 100 to 120°, and aerated occasionally until aged. In still another method aeration and pasteurization are alternated until the desired effect is attained. Usually oak chips (0.05 to 0.1 per cent by weight) are added during rapid aging to act as a catalyst and to impart a faint oak taste. Some wine makers have used oxygen instead of air to induce oxidation.

While in a sense such wines are aged, they usually lack the fine bouquet and flavor of wines aged slowly in wood. Rapidly aged wines which are overoxidized are apt to be flat in taste and lacking in bouquet. However, controlled oxidation in the presence of oak shavings, oak sawdust, or extractives from oak at elevated temperatures is capable of yielding reasonably good bulk wines.

It is advised that the makers of fine wines follow the usual slow aging process, as there is no substitute for this procedure for such wines.

Filtration.—Usually filtration is a necessary supplement to settling, racking, and fining. Several types of filters are in general use in wineries. These may be divided into two general classes in accordance with the function performed, rough or bulk filters and finishing or polishing filters. They are classified also in accordance with the design or principle used. Thus there are pulp filters, asbestos-fiber filters, filter presses of various designs, filters using fiber or asbestos pads, and porcelain candle (Berkfeld) filters.

One very well-known pulp filter (Karl Kiefer) consists of a series of thick filter-pulp disks interspersed with screens, the disks and screens

being housed in a metal cylinder. Each disk acts as an individual filter. The filter pulp or "filter mass" consists of cotton fiber or cotton fiber mixed with wood pulp or asbestos fiber, or both. After using, the pulp disks are broken up; the fiber is washed free from sediment in water and then reformed by a machine into disks for further use. This filter has large capacity and is used for bulk filtration. The wine is forced through the filter by a pump although the force of gravity can also be used.

A second form of pulp filter consists of a perforated cylinder placed inside a larger cylinder. Pulp is packed by hand in a layer over the perforated cylinder and the wine forced through this layer. This filter is inexpensive, easily operated, and fairly satisfactory. It is built by most coppersmiths who specialize in winery equipment.

Asbestos fiber on a fine metal screen is used in the large-capacity Seitz filter.

The usual filter press consists of a series of metal frames with pieces of heavy filter cloth between the frames. Another form consists of hollow clamshell-shaped disks covered with heavy cloth, the disks being housed in a metal box. The wine for either type is mixed with a filter aid, usually siliceous or diatomaceous earth (infusorial earth) that has been fired to remove earthy taste and to improve its filtering quality; such, *e.g.*, as Hyflo Super-Cel. It is possible to render the wine bottle-bright by this method of filtering; or it can be used for bulk filtration also. In California there is now in general use a filter consisting of several fine-mesh screens suspended in an enclosed cylinder. A filtering surface is built up on the screen by pumping a mixture of wine and siliceous earth through the filter. The West Coast filter is of this type. It is simple in operation and has great capacity.

Filters using pads are usually of smaller capacity and are employed for final filtration before bottling. The pads consist of asbestos, or asbestos and cotton fiber, or fiber only. These are held between metal frames, each pad acting as an individual filter. The pads are rather costly and must be discarded after use. The introduction of iron and calcium salts from filter pads, filter aid, or filter mass is sometimes an important cause of cloudiness in wine.

The candle filter consists of several large unglazed porcelain tubes closed at one end and placed in a closed metal chamber. The fine pores of the porcelain act as a filter. This filter is used only for final filtration of clear wine in order to render it bottle-bright.

Filters should be made of corrosion-resistant alloy, of hard rubber or of other suitable material which will not affect the wine. Iron, tin, and copper are particularly objectionable as minute amounts dissolved by the wine cause clouding, loss of color, and undesirable changes in flavor.

In order to furnish the pressure needed in filtration, the wine may be pumped into a tank placed 20 to 50 ft. above the filter and allowed to flow through it by gravity. The usual source of pressure, however, is a centrifugal or a rotary pump; they are preferable to a plunger-type pump because they give a uniform, nonpulsating pressure. By use of a suitable by-pass the pressure can be increased progressively as the filtration becomes slower because of clogging. Clearness of the filtrate varies inversely with the pressure, whereas rate of filtration varies directly with the pressure. There is a "happy medium" in each case that can be ascertained only by trial.

The Seitz, Ertel, and other pad filters and the Berkfeld candle filter are often used to sterilize wine by close filtration which removes all microorganisms present. They are also used very generally for final "polishing" filtration for bottling.

Fining.—Wines are often rendered clear by the use of fining agents such as gelatin, isinglass, casein, egg albumen, Spanish clay, and bentonite. These agents, either by chemical combination with the colloids or by neutralizing the electrical charge of these particles, cause their coagulation and settling. Gelatin and most of the other nitrogenous fining agents combine with, or are coagulated by, the tannin. Their use decreases the tannin content of wine and in the case of gelatin and casein causes noticeable decrease of color. In certain light wines where loss of color is not desirable egg albumen or isinglass should be used instead of casein or gelatin. Addition of tannin will also prevent the bleaching of color by casein or gelatin. The fining agents dissolved in water are thoroughly mixed with the wine which is then stored until the suspended matter settles out. It can then be racked and, if necessary, filtered.

The amount and type of fining agents to use will depend on the nature of the suspended matter and the type of wine. Since gelatin and other proteins decrease the tannin content of treated wine, tannin should be added to wines low in tannin content before adding gelatin or other protein. From 0.5 to 2.0 oz. of good tannin per 100 gal. is added to white wines and wines deficient in tannin before fining with such agents as gelatin. The usual amount of the respective fining agents added per 100 gal. is as follows: about 0.5 to 1.0 lb. of Spanish clay or bentonite; 1 to 1½ oz. of gelatin; 4 to 8 whites of fresh eggs or their equivalent in egg albumen (1 oz. of dried egg albumen); and 4 oz. of specially prepared casein. The best of the fining agents of animal origin is isinglass. This is added to white wines or red wines in preparing the wine for bottling at the rate of ¼ to ½ oz. per 100 gal.

The isinglass may be dissolved in water or wine, cold or warm. The cold method is slow but gives the best results. It is done by soaking overnight in wine or water acidified with citric acid and then grinding or

rubbing on a fine screen until dissolved. Prolonged soaking in a sulfited citric acid solution is also practiced. The isinglass sediment is very light and fluffy and care should be taken to avoid disturbing it in racking. A brilliantly clear wine results if the clarification is successful. In using this clarifying agent, add it slowly to the wine with vigorous stirring or pumping over to mix it throughly with the wine. Tannin equal in weight to the isinglass should be added several days before adding the isinglass.

In fining with gelatin only the purest grades of edible gelatin, free from objectionable odor or taste, should be used. It is now obtainable in granular or powdered form as well as in sheets. Dissolve it in hot water

Fig. 104.—Fermenting room showing 10,000-gallon fermenting vats and pomace conveyer.

to form a solution of about 2 oz. per gallon. As with isinglass tannin equal in amount to the gelatin to be used should be added to the wine several days before adding the gelatin. The gelatin is added slowly with stirring or pumping over; the wine is then allowed to settle and is later racked from the sediment. Usually 1 to 2 oz. per 100 gal. will be sufficient.

Casein is dissolved as follows: 2 oz. is added to about 1 qt. of water, and about ¼ pt. of strong ammonia water is added. The mixture is stirred until the casein dissolves. The solution is boiled until there is no longer any odor of ammonia. The solution is then diluted to 1 gal. with water. It is used in the same manner as gelatin, being precipitated principally by the acid of the wine. Specially prepared soluble casein is now available for winery use.

Bentonite, free from objectionable earthy taste, odor, and other defects (not all bentonites are free) is prepared as follows: It is prepared

by sifting the powder slowly into water or wine while vigorously stirring, 7 oz. being added to each gallon. The mixture must then be stirred and lumps broken up by rubbing until a smooth, creamy suspension results; this requires several hours of such manipulation. Before and during the use, it must be thoroughly mixed. The finished suspension is added to the wine to be clarified at the rate of from 1 to 1½ gal. per 100 gal. It settles rather rapidly, but the precipitated material can be removed also by filtration or centrifuging. Heating to 140°F. greatly hastens settling and improves the clarification. It can be used to advantage after treatment with casein. Its use will often clarify "overfined" wines to which an excess of gelatin, casein, or isinglass has been added. Wines that are cloudy, owing to overfining with gelatin or isinglass, are common, hence bentonite is a very useful supplementary fining agent. Bentonite is also used as follows: The desired amount of finely ground bentonite is weighed and is then sifted slowly into a tub of wine, as the wine flows into the tub from the tank of wine to be fined. The wine in the tub is violently mixed; and continuously pumped into the tank. The wine is pumped over until the bentonite is evenly distributed. Spanish clay in finely ground form is soaked in water for about 1 week. It is then made up and used in the same manner as bentonite.

It is usually advisable to conduct small-scale fining tests in the laboratory before attempting to clarify the cask or tank of wine in the winery. This service is often performed by commercial chemists for a moderate fee, or in larger plants by the winery chemists.

The experimental test consists simply of adding accurately measured small quantities of stock solutions of the fining agents to 100-cc. quantities of wine and noting the results after 24 hr. standing.

Significance of Volatile Acidity.—Throughout the world the soundness (and to some extent the quality) of wine is often judged, not only by its taste, but by its volatile acid content. The volatile acidity of wine is chiefly acetic acid. A small amount, usually less than 0.05 gram per 100 cc., is produced by wine yeast during normal fermentation. High volatile acidity (about 0.09 to 0.20 gram per 100 cc. expressed as acetic) is an indication of activity of acetic bacteria or of lactobacilli. The latter are often designated in California by the term Tourne, although there are many strains in this group that affect wine. They produce acetic and other volatile acids as well as lactic acid from residual sugar or tartrates.

In California, white wine containing more than 0.110 gram and red wine more than 0.120 gram volatile acid per 100 cc. may not be marketed. Wines of high volatile acidity are usually diseased or, if free of wine-disease organisms, have probably been diseased in the past and have been pasteurized and filtered or otherwise treated to kill and remove microorganisms.

For these reasons the volatile acid content of all wines is determined by the larger producers, buyers, and distributors and is used as a "yardstick" of soundness.

Pasteurization.—Often it is necessary or desirable to pasteurize wines in order to coagulate by heat colloids that may be causing persistent or recurring cloudiness, to destroy spoilage organisms, or to promote aging of certain wines, particularly Sauternes and fortified sweet wines.

Continuous pasteurizers used for this purpose consist of a heat interchanger and a heating unit. The incoming cold wine flows through the outer jacket of copper or stainless-steel pipes of the heat interchanger and the outgoing heated wine through the inner tubes of the interchanger. The pasteurized wine is cooled nearly to cellar temperature, and the unpasteurized wine is heated nearly to the pasteurizing temperature in the interchanger. Above the interchanger is a tank of jacketed pipes, or a large metal cylinder through which pass a number of small metal tubes. Steam or hot water heats the wine to pasteurizing temperature as it passes through these tubes. The heated wine then descends through the heat interchanger.

The usual temperature is 180 to 190°F., and the time at this temperature, is 1 to 2 min. Such a pasteurization destroys acetic and lactic bacteria and coagulates heat-coagulable colloids. The flavor of delicate wines is impaired by pasteurization, that of fortified wines is usually improved.

Packaging.—The finished, aged, bottle-bright wine, if it is of high quality, is bottled for the retail trade. Each major class of wine is placed in bottles peculiar to the class. Rhine wine-type wines are placed in tall tapering, narrow bottles of dark glass; red Bordeaux-type wines, in straight-sided bottles of dark glass; Burgundy-type wines, in dark bottles similar to Champagne bottles in shape; and Sauterne wines, in white glass bottles of Bordeaux bottle shape.

Bottles must be clean and as nearly sterile as possible. Corks are prepared by wetting several times with a mixture of about equal parts of brandy, glycerin, and water and allowing to stand several hours to soften. The glycerin renders the corks permanently soft and prevents sticking of the cork in the neck of the bottle. Corking machines first compress the cork to small diameter and then force the cork into the neck of the bottle by a plunger. As the cork is compressed, the expressed liquid should be wiped away before the cork enters the bottle.

Cork-lined aluminum caps of the familiar grape-juice-bottle type are also used for wine bottle closures. Most sweet wine bottles in California are closed with metal or Bakelite screw-on caps lined with cork disks, faced with glazed paper. These closures are inexpensive, are conveniently opened, and permit resealing of the bottle.

Sauterne-type Wines.—Sauterne wines of France are produced in a small area near Bordeaux and French producers contend that the name Sauterne should be applied only to the wines of that district, which is defined and limited by French statute. However, wines of similar character are produced in quantity in California, Australia, Chile, and elsewhere, and the name has come to designate a type of white wine containing considerable unfermented sugar, regardless of the land of origin. Such wines in fairness to French producers should be labeled "Sauterne type," "Chilean Sauterne type," etc.

In California the Semillon, Sauvignon Vert and Sauvignon Blanc varieties of grapes are used for the best Sauternes; these same varieties are

FIG. 105.—Oak ovals for white wine.

also used in the Sauterne district of France. The grapes are allowed to attain high sugar content, preferably 25 to 28° Balling. In the typical California process the grapes are crushed and stemmed into open fermenting vats and 100 to 200 p.p.m. of sulfur dioxide is added, together with a starter of yeast. Fermentation is allowed to ensue for 24 to 48 hr. to facilitate pressing and to extract some tannin from the skins.

The grapes are then pressed, and the must is allowed to ferment in 1,000- to 2,000-gal. ovals or tanks. If the must is very high in sugar, fermentation may cease with some residual sugar. Usually the wine becomes dry or nearly so, *i.e.*, low in sugar content. It is then aged and later sweetened by the addition of "muté," must preserved with 1,000 to 2,000 p.p.m. of sulfur dioxide.

In some cases the fermentation is arrested either by addition of 350 to 600 p.p.m. of sulfur dioxide or by pasteurizing and adding sulfur dioxide to increase the total to above 350 p.p.m. The wine is then aged, at all times maintaining the sulfur dioxide content above 350 p.p.m. in order to prevent fermentation.

Another method consists in adding a small amount of white grape concentrate and sulfur dioxide to the aged wine. Sugar has been used for sweetening but is forbidden in California. Much of California Sauterne is baked a short time at about 130 to 140°F. to age and mellow it.

Mediocre Sauterne-type wine is sometimes made from dry white wines produced from bulk wine grapes such as Tokay, Malaga, and Thompson Seedless varieties. Brandy may be added to increase the alcohol content to about 13 per cent by volume, and grape concentrate or muté is added to give the desired sugar content. The wine is then preserved with sulfur dioxide.

In France the grapes are usually attacked by *Botrytus cinerea*, "noble mold," a gray fungus that evaporates through its mycelium much of the moisture of the grapes, thereby, concentrating the must greatly. The flavor and aroma of the grapes are not seriously affected. Great care is taken in sorting and trimming the bunches. The grapes are crushed, pressed, and fermented under careful control with sulfur dioxide and pure yeast. Fermentation is arrested with sulfur dioxide, and the wine is preserved with sulfur dioxide. Much of the wine is also sweetened with muté.

In California is produced a so-called Dry Sauterne, Haut Sauterne (Sweet Sauterne), and d'Yquem-type or Chateau-type Sauterne (very sweet).

The writer has advocated the use of less sulfur dioxide in Sauterne wines and has advocated pasteurization of the bottled wine to prevent spoilage. It then is not "pickled" with sulfur dioxide and possesses a more pleasing flavor.

Sparkling Wines.—Space does not permit adequate presentation of this subject; for details see Cruess, "Principles and Practise of Wine Making," Chap. X, or Weinmann's book on Champagne making (in French).

Champagne is produced in a small area near Rheims, France, from certain varieties of grapes and in a specified manner; but Champagne-type wines are made throughout most of the civilized world. In France the Pinot grape is the principal variety used for Champagne making. A white dry wine is made in the manner, previously described, from the must pressed at once after crushing. The new wine in the following spring or summer is made clear by fining or filtration, sweetened to about 2 per cent total sugar and bottled in strong Champagne bottles. These

are corked and the corks tied securely. The bottles are stacked on their sides in a warm room for several weeks to undergo fermentation. They are then placed in racks with the bottles inclined at a high angle. Daily the bottles are turned and "jolted" by hand to force the yeast sediment to settle on the cork, a process requiring several months' time.

The necks of the bottles are then inserted a short distance into a freezing solution until a short plug of wine solidifies to ice above the cork. The cork is then loosened and removed with the plug of ice containing the yeast sediment. Brandy or sweetened brandy syrup is added to replace the wine lost in "disgorging," and the bottle is closed again at once with large, special corks, held in place by the familiar wire cage. The wine is then aged in the bottle several years before sale. Champagnes are very

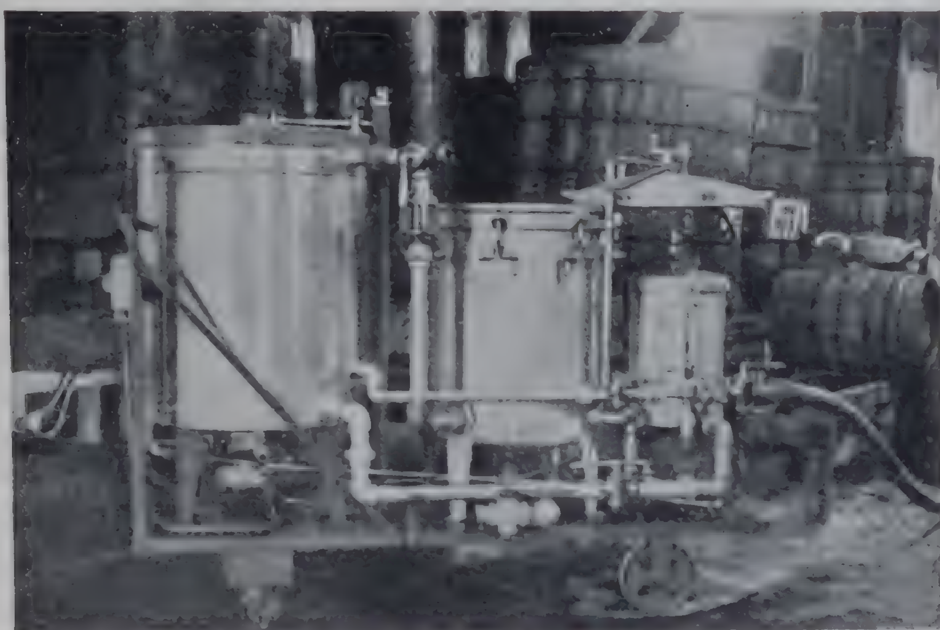

FIG. 106.—Diatomaceous earth filter, West Coast type.

dry (brut), nearly dry (sec), or of various degrees of sweetness according to the desires of the consumer.

In the Saville and Bray process, developed recently in California, secondary fermentation occurs in an inexpensive, carbonated-water type of bottle; when complete the wine is filtered cold into a Champagne bottle under pressure, brandied syrup added, and the bottle corked. Costly turning and disgorging are eliminated.

In the Charmat and similar processes the new wine is rapidly aged, detartarated by refrigeration; and secondary fermentation is conducted in glass-lined, heavy steel tanks. After this fermentation is complete (about 3 weeks), the wine is syruped, refrigerated and filtered under carbon dioxide pressure into the Champagne bottles. The wine is then aged in the bottle. This product may not be called Champagne unqualified, but is similar to Champagne in flavor and effervescence.

The desired pressure of carbon dioxide at 60°F. in Champagne is about 5 atmospheres, *i.e.*, about 70 to 75 lb. per square inch.

Sparkling Burgundy is prepared in the same manner as Champagne, except that the grapes are fermented on the skins to produce a red wine.

Carbonated wines are prepared by chilling the aged wine, usually a Moselle or Riesling type, and carbonating in a continuous carbonator, similar to those used for bottled soda waters. Champagne-type bottles are used. Usually the wine is sweetened slightly (to 2 to 4 per cent sugar) with cane-sugar syrup.

There should be also a large market for inexpensive carbonated wines packed in Crown-finish bottles, to sell at prices competitive with that of beer or common still wines.

Port.—Port is a fortified, sweet red wine which originated in Portugal and which has for many years been a favorite wine in England. Similar wine is produced in other parts of the world. In Portugal the grapes are grown and the wine is produced in the rough, hilly Douro district. The best wines are made from grapes grown on the poorer soils on the slopes; those from grapes grown on the rich alluvial soils are of coarser and poorer quality, other things being equal. A number of varieties of grapes are used in making Port. Well known varieties are the Tinta Madeira, Tinta Francesca, and Mourisco. When the grapes attain high sugar content, they are crushed, in some cases by treading with the feet, and are allowed to ferment to the desired Balling degree. The free run is then drawn off, and the grapes are pressed. To the fermenting must is added brandy of high alcohol content to arrest fermentation and to give a total alcohol content of about 20 to 22 per cent. The new wines are taken to Oporto where they are aged in large warehouses and undergo various cellar treatments to condition them for export. Some of the wine is bottled at 2 to 3 years as Vintage Port and is aged further in the bottle, often for many years. Other wines are aged in the wood until ready for consumption, usually until "tawny" in color, and should be used soon after bottling. The trade is largely in the hands of English companies.

In California, Port is made from several varieties of red wine grapes grown in the hot interior valleys; such varieties as the Zinfandel, Carignane, Mission, and Alicante Bouschet. The grapes grown in these districts are of high sugar and low total-acid content. They are crushed and stemmed into large fermenting vats, where they are allowed to ferment to about 12 to 16° Balling. The must should be pumped over frequently or the grapes "punched" frequently to hasten extraction of the color from the skins, as present demand is for Port or rather deep color. The must is then drawn off and fortified with "high proof" brandy of 180 to 190° proof (90 to 95 per cent alcohol). E. H. Twight formerly of

the University of California recommends that fermentation be continued on the skins until the desired color is attained, which often will be when the must is nearly free of sugar. The wine is then fortified to about 20.5 per cent alcohol, and grape concentrate previously fortified to 20.5 per cent alcohol is added to give the desired sugar content or Balling degree.

A standard California Port contains 20 to 20.5 per cent alcohol and tests 6° Balling (reading corrected for temperature). The Balling test is made upon the wine and not upon the dealcoholized sample.

As great care should be taken with the fermentation of Port as with that of dry red wine. The temperature should be kept below 90°F., and sulfur dioxide and pure yeast should be used.

To the drained, partially fermented pomace is added water in such amount that when fermentation is complete the liquid contains about 6 to 7 per cent alcohol. The fermented "wash" or "distilling material" is drawn off, the pomace is pressed, and the liquids are combined and distilled to give high proof brandy for fortification. The pressed pomace may also be washed with water to give additional distilling material.

The new Port is allowed to settle several weeks; is then racked; is filtered, or fined and filtered; and is refrigerated to about 16°F. for 2 to 3 weeks or for a longer time at 25 to 30°F. to cause deposition from solution of excess cream of tartar. The refrigerated wine is filtered cold to remove suspended tartrate crystals and is then aged in tanks. Within 6 months it becomes acceptable in flavor, but improves for many years. Too much Port has been marketed too young. It should be aged at least 3 years in wood. Quick aging, as previously described for dry wine, is sometimes used; or the new Port is given a short "Sherry cooking" by heating it to 120 to 140°F. for several days to hasten aging. Addition of Sherry or Madeira will have a similar effect.

A so-called "white Port" is made by fermenting the must of white grapes on the skins and fortifying as in the making of red port. Any excess amber color is removed later with vegetable decolorizing carbon. Present regulations do not permit decolorizing of red Port to make white Port. The writer confesses that he believes that a water-white "Port" made by decolorizing wine with charcoal does not deserve the name of Port.

Muscatel.—Grapes of several varieties of grapes of Muscat flavor are used in Italy, Spain, California, and Australia for the preparation of sweet wines. In Malaga, Spain, considerable "Moscatel" is made of white Muscat grapes or of this variety mixed with the Pedro Jimenez. It is made usually from the second or third crops of grapes, which may be partially dried before crushing in order to give a very sweet must. Fermentation is arrested by addition of brandy as in making Port. A caramelized, highly concentrated must may be added to impart color

and flavor. It is a wine that is aged in the wood, often by the Solera system similar to that used for Sherries in Jerez, Spain (see page 671). It is a wine that improves greatly with age.

The Muscat and other grapes of Muscat flavor are grown throughout Italy, being used for the "Moscato spumante" (sparkling Muscat) of Piedmont in Northern Italy, the famous Est! Est!! Est!!! (sweet Muscatel) of Montefiascone in Central Italy, and the sweet "Moscato" of Syracuse in Sicily.

In California the Muscat of Alexandria, which is widely grown in the San Joaquin Valley for raisins, is utilized in large quantities for preparing Muscatel, a sweet fortified wine in some respects similar to the

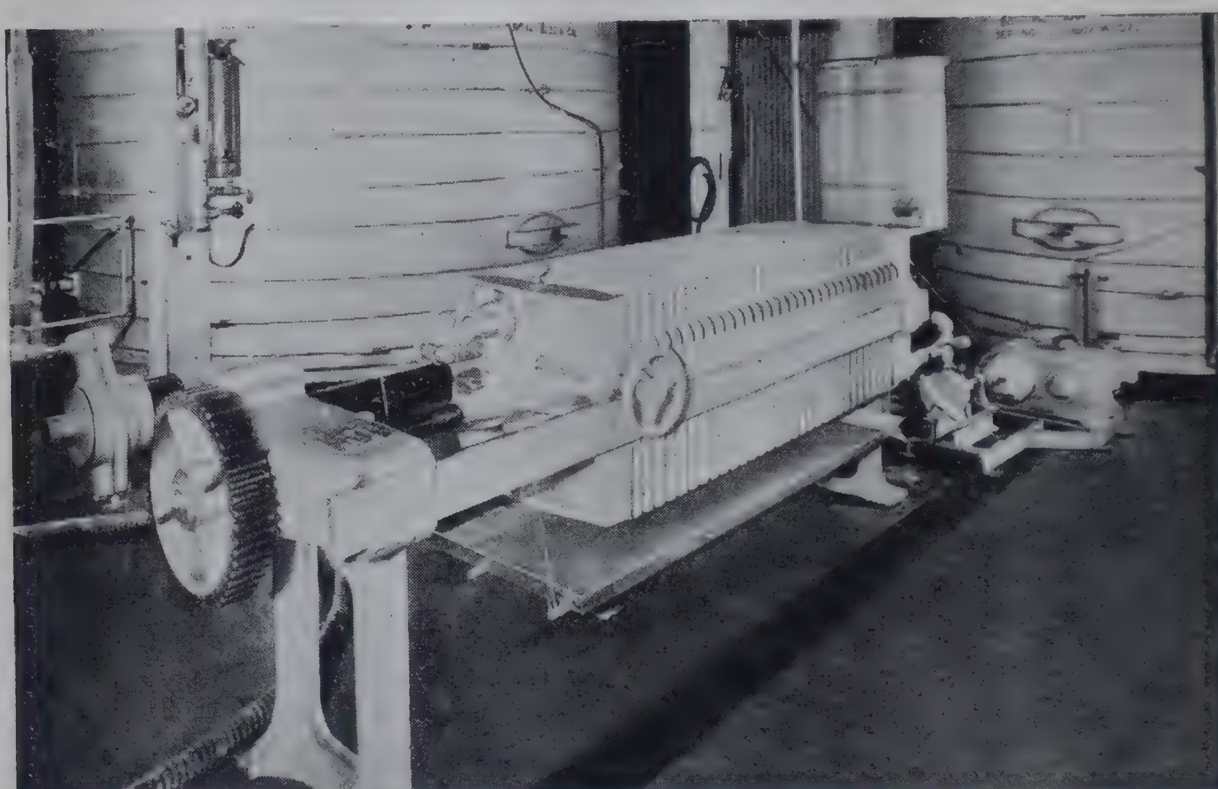

Fig. 107.—Filter press of corrosion-resistant alloy for wine filtration. (*Courtesy Shriver Company.*)

"Moscatel" of Malaga, Spain. The wine is usually lighter in color than that of Malaga.

The grapes are allowed to become as ripe as possible (about 23 to 28° Balling). They are crushed and stemmed into large rectangular concrete vats or circular, redwood vats holding about 10,000 gal. each. Sulfurous acid or metabisulfite should be added equivalent to about 100 p.p.m. of sulfur dioxide. Pure yeast should also be added as previously described for dry wine. These control measures are often omitted. Unless sulfur dioxide is used, lactic and acetic bacteria are very apt to develop during fermentation and spoil the product. The writer has observed uncontrolled fermentations in which the volatile

acidity increased in 48 hr. of fermentation to 0.30 gram per 100 cc., more than twice the federal legal limit. Sound, well-made Muscatel, Port, and other fortified, newly made, sweet wines should contain less than 0.06 gram volatile acidity per 100 cc.; usually less than 0.04 gram per 100 cc.

It is customary to conduct the fermentation in the presence of the skins and seeds in order to extract some tannin and the maximum flavor and aroma. Normally fermentation is allowed to proceed to about 14° Balling. Cooling should be employed to keep the temperature below 85°F. The fermenting must of about 14° Balling is drawn off, transferred to the fortifying tank, analyzed at once for alcohol content by the federal agent ("U. S. gauger"), and the calculated amount of high-proof brandy is weighed by him in a special, closed tank or in barrels and added to the must to arrest fermentation. The mixture is stirred by a mechanical stirrer or by compressed air to thoroughly mix the brandy and must. The fortified wine is then analyzed and pumped to storage tanks where it is allowed to deposit its "lees" of yeast, tartrates, and pulp for 2 or 3 weeks. Or in periods of urgent demand for new Muscatel wine, it is allowed to settle several days only and is then drawn off and filtered, or fined and filtered.

The racked wine in many plants is clarified with bentonite, or with casein and bentonite, sometimes at 120 to 140°F., the elevated temperature favoring rapid coagulation and settling of the finings. After settling, the clarified wine is filtered and is then refrigerated to near the freezing point of the wine, *i.e.*, to about 16°F. to hasten deposition of excess cream of tartar. It is then, like Port, filtered cold and aged in large tanks. Or it may be rapidly aged by aeration at low temperature, followed by pasteurization or a short "Sherry cook" of several days at 120 to 140°F. For the best results the wine should be aged in the wood for at least 4 years. It improves in quality for many years.

There is a growing demand for "dry Muscatel" a fortified Muscatel of low sugar content. It has a less pronounced Muscat flavor than sweet Muscatel, as sugar appears to be necessary for retention of the peculiar aroma and flavor of this grape, a fact known long ago to the vintners of Italy.

Muscatel and Port are dessert or "between-meal" wines; they are too sweet and of too high alcohol content for use with the meals. The usual commercial standard Muscatel is of about 6° Balling and 20 to 20.5 per cent alcohol. It is impossible to make all Muscatel or any other fortified sweet wine of exactly 6° Balling. Consequently some is made of considerably higher Balling degree for use in sweetening wines lower than 6° Balling; or fortified grape concentrate of 20.5 per cent alcohol may be added to wines of low sugar content.

At present Muscatel is often diluted with Angelica made from cheaper grapes of poorer varieties than the Muscat. California state regulations require at least 51 per cent of Muscat wine in Muscatel; but this requirement is impossible of enforcement because there is no known method, except the very imperfect one of tasting, of determining the Muscat content of wine.

Aleatico.—The Aleatico is a red Muscat grape used extensively in Italy in making a red or pink sweet wine of Muscat flavor. Some such wine is made in California from this variety without fortification. It is preserved with sulfur dioxide, much as is sweet Sauterne. Probably the wine would be more pleasing if preserved by pasteurization in the bottle.

Angelica.—This is a Californian, sweet, fortified wine made in the same manner as Muscatel; the only difference being that grapes of other varieties than Muscat are employed. The Thompson Seedless (Sultanina), Malaga, and Tokay are commonly used for the purpose. This wine is neutral in flavor.

Tokay.—The most famous wine of this name is produced in Hungary. The European spelling is Tokaj. A fortified wine of the same name, but of different character, is made in California. The Californian Tokay is often a blend of Angelica and enough Port to impart a pink color; it may or may not contain added Sherry.

In making Tokaj, in Hungary, the Furmint is the principal grape used. Most of the crop is allowed to partially dry on the wines. Tokay Essence is made from the very sweetest, partially dried grapes, Tokay Aszu and Tokay Szamorodin from a mixture of partially dried and normal grapes. According to Schoonmaker and Marvel, Tokay wines are not fortified. The Essence is extremely sweet, almost a syrup, and very costly. The Aszu and Szamorodin are much less sweet. Agents of the Hungarian Government must examine, analyze, and approve all wines for export, assuring the purchaser of wines of good to fine quality and of authentic origin.

Sherry.—In the British Empire and the United States Sherry is the best known of the wines of Spain. It takes its name from Jerez de la Frontera, a town in the heart of the Sherry district in southern Spain. The well-known character of this wine is derived in part from the varieties of grapes used, the Palomino and Pedro Jimenez; in part from the peculiar soil in which the grapes are grown, *viz.*, a highly calcareous soil; the hot climate of Jerez; the partial drying of the grapes in the sun; the employment of film yeasts, and to the Solera system.

In Spain the grapes are picked thoroughly ripe, but many also are often spread on esparto grass mats to dry in the sun for several days before crushing. The grapes are crushed and pressed into large oak or chestnut

casks. It is stated that gypsum, $CaSO_4$, is usually added to the crushed grapes; insoluble calcium tartrate and soluble potassium sulfate are formed, the latter remaining in the wine to impart a slightly bitter taste. This procedure is termed "plastering." Sulfur dioxide or metabisulfite may or may not be added. Fermentation in the warm Jerez climate is rapid. The barrels are allowed to stand about three-fourths full without removal of the lees for several months. Slowly a film of yeast, the "flor," or so-called Mycoderma film forms. It was formerly thought to be a nonsporeformnig Mycoderma yeast. Dr. Schanderl of Geisenheim and others have found it to be a film stage of certain true wine yeasts, of the Saccharomyces genus, of the Jerez district. Some strains of the yeast have refused to form spores in tests made in this laboratory; others form spores only under certain, very special conditions. Therefore, not all Jerez yeasts are typical Sacch. ellipsoideus yeasts.

According to most accounts, the film is allowed to develop for several months, as long as 18 months, or longer. During this period some of the fixed acid and of the volatile acid is destroyed and characteristic changes in flavor are produced by the yeast. The wine is then racked and lightly fortified with brandy; further fortification is given later.

The new fortified wines are classified according to type and quality and are then aged in the oak for several years. In the Solera system used for the finer Sherries a small proportion of the oldest Sherry is removed each year for flavoring other Sherry or for bottling. The Sherry thus removed is replaced by well-aged Sherry of the same type and to the cask from which the latter is removed is added younger wine of the same type "and so on." By this procedure the oldest "Solera" Sherry is of constant character. According to some writers, the Solera is usually a stack of four tiers of barrels. At intervals some of the oldest wine is drawn from the lowermost barrels; from those in the second tier is drawn wine to replace it; wine from the third tier is drawn to replace that taken from the second tier. The second is filled from the topmost barrel. Wine from the "criadera" (cellar or "bodega") is used to fill the first tier. The wine from the lowermost barrels is very precious for blending purposes and is the "backbone" of the fine Sherries. According to de Castella the "flor," *i.e.*, yeast film, is allowed to grow on the Solera wines continuously.

A "Fino" is very dry and of pale color with none of the cooked taste of common Sherry. Amontillado is also dry and somewhat darker in color. Its name comes from that of Montilla, a small town of Southern Spain. Manzanilla is a pale, dry Sherry-type wine of extraordinarily clean, slightly bitter, characteristic flavor. Oloroso and Amoroso are sweeter and darker in color than the foregoing wines and usually contain added, boiled down dark-colored must, which imparts color and a cooked

taste. "Golden or Brown Sherry" and "East India" Sherries are even darker than Amoroso and Oloroso.

In California "plastering" with gypsum, "flor" yeasts, and the Solera system are not used. Also other grape varieties than the Palomino and Pedro Jimenez are used. The grapes are crushed and stemmed into large vats. They may or may not be pressed at once; if not, they are allowed to ferment on the skins 24 to 48 hr., and the must is then drawn off and allowed to ferment nearly to dryness before fortifying to about 20.5 per cent alcohol to arrest fermentation.

The new "Sherry material" (fortified new wine) is allowed to settle several weeks. It is then racked, filtered, refrigerated 2 to 3 weeks to remove excess tartrates, and then "cooked." Cooking consists in heating the wine to 130 to 140°F. by a stainless-steel or copper coil suspended in the wine held in a large redwood tank. The usual "cook" is at 130 to 140°F. for 3 to 4 months. During heating the Sherry material is aerated occasionally or continuously by pumping over, as part of "sherryizing" is due to oxidation.

A better Sherry is obtained by first aging the Sherry material for 1 to 2 years at cellar temperature before cooking; and also by using a lower cooking temperature, *viz.*, about 120°F. In Spain Sherry cooking is usually not employed, although a similar effect is attained by adding boiled-down must and by storage in partly filled casks in warm warehouses.

Circulation of hot water through the Sherry heating coils is preferable to steam, since the latter frequently causes scorching of the Sherry.

When the desired flavor is attained, or when the Sherry breaks (a small sample settles clear on standing) the new Sherry is conditioned by aging in wood (preferably at least a year), pasteurizing, fining, and filtering.

California Sherry may be dry, medium dry, or sweet; the present consumer preference being for dry to medium-dry Sherry.

Madeira.—This is a fortified wine, or rather a "family" of cooked, fortified wines ranging from dry to very sweet, produced on the island of Madeira about 350 miles off the coast of Morocco. The island is a Portuguese possession, although the export trade is principally in the hands of the British. The principal grapes are the Boal de Madeira, Malvasia, Sercial, and Verdelho.

The grapes are (according to Thudichum) crushed and pressed by the growers who deliver the must to the shippers. There it is allowed to ferment and is fortified; often with several small additions of brandy rather than a single, large addition.

The fortified wine is "cooked," *i.e.*, stored in rooms at 100 to 140°F., until it attains the desired flavor and bouquet. This procedure is

similar to that used in California for cooking Sherry and Madeira. Blending, aging and fining, etc., follow fortification.

In California a sweet wine of Madeira type is made in a manner similar to that used for Sherry, being sweeter than the usual California Sherry. It may also be made by blending Angelica and Sherry.

Marsala.—The procedure for making this famous wine, in Marsala, Sicily, is said to have been discovered by an Englishman, John Woodhouse, late in the eighteenth century. To the new wine are added high-proof brandy and a boiled-down must, "vino cotto," which imparts the characteristic brown color and "scorched" taste of this wine. It is aged and handled in a manner similar to that used for Sherry.

Unfortified Sweet Wines of High Alcohol Content.—It was demonstrated by Cruess, Brown, and Flossfeder in 1916 that wines of more than 18 per cent of alcohol by volume could be prepared by syruped fermentation, *i.e.*, by making several additions of grape concentrate or of chopped raisins during fermentation. By normal fermentation the maximum attainable alcohol content of grape must is about 16 per cent. If the syruped fermentation method is used, to the fresh must are added about 150 p.p.m. of sulfur dioxide and a starter of pure selected wine yeast of proved high alcohol-forming power. The fermentation is conducted at not above 75°F. since alcohol formation is not so satisfactory at higher temperatures. Frequent aeration or passage of a slow stream of air or oxygen through the fermenting must favors high alcohol production. When the Balling degree has decreased to 5 to 0°, grape concentrate is added to increase the Balling about 5°; several similar additions are made subsequently, according to the sugar content desired in the finished wine.

Eventually (in 4 to 6 weeks) fermentation ceases, usually at 16.5 to 19 per cent alcohol. The wine is then treated as any fortified sweet wine of similar type, except that brandy is not added. Excellent unfortified Sherry, Port, Madeira, Angelica, and Muscatel type wines have been made experimentally by this method.

Owing to the fact that there is no dilution of these wines with brandy, they contain much higher nonsugar extract than fortified sweet wines; hence are richer in flavor.

American Wines Other than Californian.—While more than 90 per cent of the commercially produced wine of this country is made in California, nevertheless an important wine industry exists in the eastern United States and near Lake Erie in Canada. The Vinifera varieties of grapes grown in California do not withstand the severe climate of the East, South, and Middle West. Consequently the native varieties are used for wine, or Californian grapes are imported for the purpose.

Excellent sparkling wines of Champagne type are made in the Finger Lakes region of New York. Wines somewhat similar in composition to Claret, Burgundy, Sauterne, Riesling, Port, Sherry, and others but with the characteristic foxy flavor of the eastern grape varieties are made in New York, Ohio, and New Jersey.

It is usually necessary to add sugar to the musts of the grapes grown in these regions in order to secure a wine properly balanced in respect to alcohol content and total acidity.

The Catawba is one of the best of the varieties used for wine making in New York and Ohio. Fortified sweet Catawba is a very pleasing dessert wine.

In the Southern States the Scuppernong, a native grape of greenish color, and the James and Flowers, also native varieties but of black color, are popular for wine making. These grapes possess a very strong flavor and aroma, even stronger than those of most Labrusca varieties of the North. According to Wagner, sugar must be added in making wine from them.

Since the Concord is the most abundant, it is used in greater quantity than other native varieties for wine making. Unfortunately it is not so satisfactory for this purpose as some varieties at present available only in relatively small quantities. The Catawba, Delaware, Norton, Clinton, Cynthiana, Diamond, Missouri Riesling, and several others are considered superior to the Concord.

Blends of Californian wines and those made of eastern varieties have marked possibilities, since the former are often lacking in distinctive flavor, aroma, and bouquet, whereas the latter usually have a superabundance of these characteristics. The writer believes that certain Labrusca varieties could be grown in California to advantage for wines to be used for blending with those made from Vinifera varieties.

Those interested in planting vineyards or establishing wineries in the East or Middle West are advised to consult the specialists of the New York Agriculture Experiment Station at Geneva, N. Y., where for many years investigations in grape growing and grape breeding have been conducted and where an extensive wine research program is now under way.

Citrus Fruit Wines.—The juices of oranges and grapefruit, when obtained by burring the halved fruit, as for use in canning, and when sweetened with cane sugar, give on fermentation and aging fairly palatable wines. However, the wines tend to darken rapidly and acquire a Sherry flavor; but this tendency is minimized if the wines are lightly decolorized with vegetable decolorizing carbons (a fact discovered by investigators of the U. S. Dept. of Agr.). Sulfur dioxide and pure yeast must be employed in order to secure satisfactory fermentation.

When fortified and treated appropriately, Sherry-like and Madeira-like wines can be made from fermented orange juice. Champagne-like orange wines can also be made. Orange juice is an excellent medium for yeast; consequently fermentation is very rapid and alcohol production is high. If the whole fruit is crushed and pressed without subsequent removal of the essential oil, fermentation is very slow or may be completely inhibited. However, the essential oil can be removed by centrifugal separation, and then the juice ferments satisfactorily.

Berry Wines.—In the Pacific northwest of the United States and British Columbia considerable wine is made from loganberries. By one procedure found satisfactory in this laboratory, the berries are crushed and about 100 p.p.m. of sulfur dioxide and pure yeast are added. After 24 to 48 hr. fermentation, the free-run juice is drawn off, and the residue is pressed in an apple juice press. To the fermenting must is added cane sugar calculated to give, when fermentation ceases, a wine of 15 to 17 per cent alcohol and 3 to 10 per cent of sugar. The new wine is then treated in much the same manner as any dry red grape wine. It ages quickly and is a pleasing beverage. The addition of some water to the juice before sugaring is usually necessary to give a wine of properly balanced flavor. As addition of water dilutes the yeast foods present, it may become necessary to add ammonium phosphate. Loganberry wine is a very pleasing dessert wine.

Similarly, wine may be made from blackberries and raspberries.

Fortified sweet wines and liqueurs made from berries are very satisfactory. The procedure is similar to that used in making Port from grapes except that sugar must be added.

"Hard Cider" (Apple Wine).—There are two common types of cider or fermented apple juice. In France and England special varieties of apples of very high tannin and sugar content are used for the purpose. The wines are made in much the same manner as French dry white wines, sulfur dioxide and pure yeast being employed and the wines aged in the wood very carefully. These wines are dry, are of relatively high alcohol content, and are respectable competitors of good, dry white grape wines.

In America hard cider often signifies a partly fermented, apple juice that may contain 4 to 6 per cent of alcohol and several per cent of residual sugar. Our table varieties of apples are unsuited to the production of ciders of the French type. Nevertheless, such varieties as the Winesap, Stayman, Spitzenberg, Gravenstein, and Newtown Pippin grown in cool regions give fairly satisfactory ciders by the following procedure; those grown in Washington and Oregon are sufficiently high in total acidity for the purpose: The apples are crushed in a hammer-mill-type crusher and pressed. To the fresh juice are added about 100 p.p.m. of sulfur dioxide, pure wine yeast, and sugar to increase the density to

about 22° Balling. If fermentation becomes sluggish, it may be necessary to add yeast food, *i.e.*, about 0.02 to 0.05 per cent of ammonium hydrogen phosphate.

When fermentation is complete, the new cider is racked and filtered. It is then aged in the wood, preferably in large oak casks. For most consumers a small addition of cane sugar to the aged cider is desirable. The cider should be pasteurized at about 150°F. to coagulate heat-precipitable proteins, cooled, filtered, carbonated, bottled, and pasteurized in the bottle at 140°F. for about 30 min.

Winery By-products.—In California the principal by-product is brandy made by leaching the fermented pomace and distilling the resulting wash. This brandy, of 180 to 190 proof, is used principally for fortifying sweet wines.

Some of the pomace is dehydrated in revolving-drum driers heated by a natural gas flame and similar in appearance to cement kilns. The dried pomace, largely seeds and skins, is ground in a hammer mill and used as part of the ration for dairy cattle and other livestock. On the dry basis it contains about 10 per cent of protein, about 30 per cent of crude fiber, and 4 to 5 per cent of oil. It is low in digestible carbohydrate but is of value for its nitrogen content.

The crude lees, or sediment remaining after racking, consists of yeast, cream of tartar, and pulp mixed with wine. Much of this sediment of thick, creamy consistency is distilled for recovery of brandy and the residue extracted for cream of tartar. If the hot waste liquid from the still is filtered and allowed to cool, considerable cream of tartar separates. In some wineries the lees are pressed in heavy bags, and the residue is dried in the sun for sale to cream of tartar producers. The dry yeast would undoubtedly be useful as a chicken food because of its high content of B and G vitamins.

Cream of tartar crystallizes on the walls of wine tanks as "wine stone" or argols. These crystals are periodically scraped from the tanks and find ready sale to cream of tartar manufacturers.

The pomace has only slight value as a fertilizer but is of value for improving the texture of heavy soils, particularly if the pomace is admixed with lime.

In France considerable pomace is dehydrated, the seeds separated from the skins, and the seeds ground and extracted with an oil solvent, such as carbon disulfide or trichloroethylene, for recovery of grape-seed oil, valuable in soapmaking and for use in paints, as it is a semidrying oil. Experiments made in this laboratory indicate that the seeds can be readily separated from the skins after drying if the dry pomace is rubbed vigorously between moving screens and the skins winnowed out by a blast of air.

Probably use of the dry pomace as a stock food affords the best method of utilization at present; although feeding tests by the Animal Husbandry division of the University of California indicate that it is but little better than wheat straw as a stock food.

Dry apple pomace is rich in carbohydrates but deficient in protein. If dried and mixed with grape pomace, both would be enhanced in value for use as a stock food.

Diseases and Defects.—Wine improperly fermented or treated is subject to a number of bacterial and nonbacterial diseases and defects which impair its color and flavor. To avoid these troubles, the wine should be safeguarded from harmful microorganisms and from contamination with metals, especially iron, copper, and tin. Stainless steel, nickel alloys, and certain other metals and alloys should be used for all equipment in contact with the wine. All the surfaces with which the wine comes in contact should be thoroughly cleaned and washed immediately after use and again before use. When not in use, metallic surfaces should be kept perfectly dry; wooden surfaces should be preserved from bacterial or mold growth by sulfurous acid or hypochlorite solutions.

The use of fluorides or fluosilicates as disinfecting agents is dangerous since the substances are highly poisonous. Empty casks should be sulfured or treated with hypochlorite; vats should be limed, *i.e.*, either filled with water containing a large excess of lime or painted with a thick milk of lime. Casks or vats which have contained spoiled wine should be thoroughly cleansed and disinfected before use. Painting the surface with strong metabisulfite solution and leaving it for several days will usually sterilize the wood. Extreme sanitary conditions should be maintained in the winery, especially in the storage and bottling rooms.

Floors should be concrete, sloping, well surfaced, and provided with convenient and adequate drains.

All equipment, such as pumps, hose lines, filters, and containers with which diseased wine has come in contact or in which it has been stored, should be disinfected with steam, strong metabisulfite solution, or hypochlorite solution. Filter pulp is a particularly dangerous source of infection after it has been used with diseased wine but is easily sterilized by heating in boiling water or by soaking in sulfur dioxide or metabisulfite solution (about 1 per cent) for several days.

Nonbacterial Defects of Wine.—This subject is discussed fully by de Castella. The wine defects not directly caused by microorganisms are generally called "casse," from the French *casser*, to break. There are several types of such defects, among which are the following:

1. *Brown, Yellow or Oxidasic Casse.*—This is characterized by clouding and changes of color on exposure to air, red wines turning brown and white wines becoming yellow. These changes are caused by an enzyme

known as oxidase, normally present in small quantities in the grapes and abnormally plentiful in moldy grapes. A wine affected with this casse may be protected from the action of the enzyme by the use of sufficient sulfur dioxide or metabisulfite or by destroying the oxidase by flash pasteurization at 185°F. This form of casse is less common in America than in France but may be expected in any wines made from moldy grapes.

2. *Blue, Black, or Ferric Casse.*—This is due to the presence of excessive amounts of iron in the wine and becomes evident on oxidation of the iron, particularly on exposure to the air. The wine becomes dull, assuming a bluish, or in extreme cases, a black tint. Many of the white wines made in California in recent years exhibit this form of casse. The excess iron present in such wines is a result of solvent action of the must on the iron of the crusher, sump, stemmer, and must line and of the wine on pipe lines and other iron or steel equipment. As little as 10 p.p.m. (10 mg. per liter or 0.001 per cent) of iron dissolved from iron and steel equipment will cause serious iron casse of white wines. The defect is less noticeable in red wine. White wines, perfectly clear when bottled, frequently develop cloudiness due to iron casse, several days to several weeks after bottling. The iron is present in the wine at first as ferrous salts or reduced iron salts; on oxidation to the ferric state, precipitates form with the tannin, phosphates, and certain proteins, giving the wine a hazy or cloudy appearance.

It is simpler to avoid this defect by use of nonferrous, corrosion-resistant metals than to treat wine that has become affected.

One method of treatment consists in addition of a small amount (0.05 per cent) of tannin, oxidation of most of the iron to the ferric condition by moderate aeration, and clarification with casein. Or aeration may precede addition of the tannin.

In Germany potassium ferrocyanide has been used to remove excess iron from wines. However, if too much is added, poisonous prussic acid will form in the wine, and for this reason its use is dangerous and inadvisable except under control of a state or federal chemist.

Oxidation of the wine to precipitate iron in combination with tannin, by treatment with oxygen in a special apparatus or by the use of activated charcoal which has absorbed oxygen at low temperatures, has been suggested as a means for removing iron. Another method is that of addition of moderate amounts of tartaric acid, oxidation, and refrigeration. The iron salts are precipitated together with the cream of tartar.

3. *White Casse.*—This is also due to the presence of iron in excess. The precipitate contains phosphates and complex organic colloids. A whitish or milky cloud forms when the wine is exposed to air. The

cure, as for blue casse, is removal of the excess iron. It is less common than ordinary iron casse.

4. *Potassium and Bacterial Casse.*—Potassic casse, caused by excess potash, and certain other forms of casse, such as bacterial and aldehydic casse, are uncommon. In bacterial casse certain substances formed by the bacteria cause, after fining or filtration, the formation of colloidal precipitates that render the wine cloudy.

5. *Sulfide Taste.*—Occasionally sulfur present on the grapes or in the tanks is reduced by yeast to hydrogen sulfide which gives an offensive taste and odor to the wine. It can be removed by aeration. Addition of sulfur dioxide usually will convert it to elemental sulfur.

Bacterial Diseases of Wine.—The quality of the wine may be impaired by the activity of microorganisms such as *Mycoderma* ("wine flowers") or acetic acid (vinegar-sour) bacteria which grow only in the presence of notable supplies of free oxygen and whose activity may be inhibited by excluding air from the wine. It is also subject to attack by certain microorganisms, such as slime-forming, lactic, and mannitic bacteria, which grow best in the absence of free oxygen.

1. *Mycoderma.*—Wine exposed to air will usually, in a few days, be covered with a chalky, whitish film, thin and smooth at first, but gradually becoming thicker and finally rough and wrinkled. This film is what is known to the wine makers as "wine flowers," and is composed of yeast-like organisms termed loosely *Mycoderma vini*. It is likely that other genera than Mycoderma are involved. These organisms are strongly aerobic and can develop only on the surface in full contact with air. They may render wine insipid and cloudy. They attack the extract, fixed acids, and alcohol. By keeping the containers full, the wine can be safeguarded from them.

However, in the Jerez district of Spain, as previously stated, a film yeast is allowed to grow for a time on the new wine to hasten aging and to impart a desirable flavor to Sherry (see page 671). It is not *Mycoderma vini* but a true yeast.

2. *Acetic Bacteria.*—The film formed on wines of low alcoholic content exposed to air is often different from that of *Mycoderma vini*. It will be thinner, more nearly transparent, smoother, and tougher and will consist of extremely small rod-like bacteria. These produce acetic acid (vinegar acid) from alcohol. Most of the acetic bacteria from California wines studied in this laboratory do not form films. When acetic acid is perceptible to the taste, the wine is spoiled. Wines high in alcohol are less liable to acetic fermentation than weaker wines. Sound wines containing over 14 per cent by volume are almost immune, but such wines may be spoiled during fermentation by the growth of acetic bacteria on the

exposed floating cap of pomace. When an abnormal amount of acetic acid is produced before or during fermentation, it interferes with or stops the work of the yeasts. Avoidance of prolonged exposure of the wine to air will prevent vinegar fermentation which occurs only in the presence of oxygen. If the wine begins to turn sour, add about 2 oz. of metabisulfite per 100 gal., or better, pasteurize the wine immediately. The present federal legal maximum limits of acetic acid are 0.12 gram per 100 cc. for white wines and 0.14 gram per 100 cc. for red wines.

3. *Slime-forming Bacteria.*—In most cases only young white wines in closed casks or bottles exhibit this defect. A slimy wine has an oily appearance, pours without splashing, and in extreme cases becomes very cloudy and will hang from a glass rod in strings. Alcohol above 13 per cent, free tartaric acid, tannin, and sulfurous acid in small amounts usually prevent this disease. It is rare in California and is usually not serious since it disappears under ordinary cellar treatment. Addition of tannin, about ½ to 1 oz. per 100 gal. to wines low in tannin content and addition of about 100 p.p.m. of sulfur dioxide (3 oz. of metabisulfite per 100 gal.) will aid in preventing this disease and in curing it. Under the microscope the bacteria are seen in long rosary-like chains.

4. *Tourne Bacteria.*—The most serious and perhaps the commonest disease of wines is Tourne, characterized by persistent cloudiness, mousiness, and other disagreeable odors and flavors, increase of lactic acid and volatile acidity, and injury to or complete destruction of the color. The defects of such wines are due to the growth and activity of so-called Tourne bacteria, a term which is rather loosely used to cover several closely related forms of rod-like lactobacilli. Müller-Thurgan and Osterwalder have described a number of lactobacilli from wine. Among them are *Lactobacillus mannitòpoeus*, *L. Gayoni*, and *L. tartarooph-thorum.* The tourne organism of California wines has been described by Douglas and Cruess as *L. hilgardii*. Light wines or low acidity are most subject to this disease. It can usually be prevented by the use of sulfur dioxide or metabisulfite during fermentation and by the proper use of sulfur dioxide and care during aging. High alcohol content and high tannin content discourage but do not completely prevent its growth. Close filtration to remove all the bacteria present or pasteurization to kill them will usually stabilize wines not too badly affected by Tourne. Pasteurization at 180°F. is recommended in preference to the 140° usually found in texts. It should be practiced at the first appearance of long rod bacteria. Addition of 75 to 100 p.p.m. of sulfur dioxide (1½ to 2 lb. of metabisulfite per 1,000 gal.) will often prevent further spoilage. It should be followed by fining and close filtration to remove bacteria. Wines affected with Tourne to only a moderate degree may be distilled; those badly affected are valueless. Sound wine should never be blended

with a mousy wine or placed in an unsterilized cask which has held mousy wine.

Tourne bacteria under the microscope consist of long, thin rods often joined in pairs at an obtuse angle. They are nonmotile.

5. *Mannitic Bacteria.*—Wines which stick during fermentation, especially when they have attained a temperature of 100°F. or above, are subject to the attack of mannitic bacteria, which form volatile acid and mannite from the grape sugar. A "sweet-sour" wine results which is often completely spoiled. Since the bacteria grow best at high temperatures (about 100°), they can be discouraged by cool fermentation. They are very sensitive to sulfur dioxide and easily prevented by its use. Increase of acidity by addition of citric or tartaric acid and addition of sulfurous acid also discourage their growth. The bacteria appear under the microscope as rather thick rods of medium length.

6. *"Cottony Mold" Spoilage.*—In California and Australia fortified sweet wines often develop a voluminous, cotton-like deposit, made up of long chains of rod bacteria. The organism appears to be a lactobacillus. It is easily held in check by maintaining a concentration of 75 to 100 p.p.m. of sulfur dioxide in the wine. It has been described by Douglas and McClung.

7. *Other Bacterial Diseases.*—Wine may turn bitter through the activity of certain bacteria or become sour by action of lactic acid bacteria, related to the Tourne organism. It may be impaired in other ways by other microorganisms developing in the absence of air. Sulfiting or pasteurization will tend to inhibit their activity.

Tasting of Wines.—The art of wine tasting can be learned best by practice under the direction of an experienced and capable judge of wines. However, a few suggestions and facts may be set down for the benefit of those who may wish to improve their ability to judge and classify wines. Such ability is necessary if a wine producer or bottler is to realize the most from his wines. First, a keen and discriminating palate and keen sense of smell are essential to successful tasting. A good memory for taste and odor is highly desirable in order that, when a wine is tasted, it may be compared mentally with wines of similar character tasted in the past.

Smoking is very harmful to the perception of the organs of taste and smell. One should not smoke for at least 3 hr. before tasting.

The taste is usually keenest in the morning. If tasting wine is to be done after breakfast the meal should be light and of neutral flavor.

A thin-walled, stemmed wine glass of fairly large size is to be preferred to a small glass or one with thick walls, as the taster may note the bouquet better with a large glass and can warm the wine with his hands if the walls of the glass are thin.

The wine should not be too cold when tasted. The writer prefers to taste dry red wines at about 65 to 70°F. and dry white wines, Sauternes and fortified wines, at about 60°F., although white wines are usually served at considerably lower temperatures for use on the table. The flavor and aroma are more volatile at the higher temperatures.

In tasting wine the writer fills the glass about one-third full. First it is held toward the light and the color and clearness carefully observed. The glass is gently rotated to cause the wine to wet the sides of the glass to better observe the color. A new red wine will usually be violet red in color; a well aged one, red to brick red without a purplish or violet tint; a very old one, brownish red. Rhine-wine-type white wines and Chablis-type wines should be pale in color, not straw yellow or amber. Red wines vary greatly in accordance with the type. A French Burgundy is lighter in color than a Chateau Neuf du Pape; and a California Claret is lighter than a Californian Burgundy. Californian Sauternes are often darker in color than the French Sauternes. Fortified, uncooked white sweet wines, such as Angelica and Muscatel, should be light to medium amber, not dark amber, in color. Sherry varies from pale amber to dark brown according to the type. Old Port is usually tawny in color; young Californian Port is usually light red in color.

The bouquet of the wine is next observed by rotating the glass and warming the glass in the hands to volatilize the esters, etc. The bouquet is inhaled deeply, and its various qualities mentally are recorded. If the wine is high in volatile acidity, this defect may often be observed in this manner. Other off odors, if present, should be recorded, *e.g.*, mustiness, odor from filter aid, etc. The aroma of the fresh grapes is often perceptible, particularly of such varieties as Muscat, Semillon, Aleatico, Sauvignon, Riesling, and Muscadelle du Bordelais. The bouquet proper is considered by some tasters to be the odor due to esters and other compounds formed during fermentation and aging and is thus judged separately from aroma.

Having noted carefully the principal characteristics of the bouquet and aroma, a small amount of the wine is taken into the mouth and rolled about on the tongue. If one may at the same time inhale and draw air through the wine to the back of the palate and nostrils in a sort of "mouth gargling" operation the flavor characteristics become more evident. Usually the taster does not swallow the wine. The first taste impression, the impression while the wine is in the mouth and for a half minute after spitting it out are all of importance in judging the taste of the wine. Some of the more important taste characteristics are volatile acidity, total acidity, astringency (tannin), sugar content, flavor of the fresh grape, "newness," aldehyde, esters, age, sulfur dioxide, yeast flavor, oak or other taste of wood, and the presence or absence of such defects in taste as

moldiness, "corky" taste, wine flowers taste, excess aldehyde, excessive sulfur dioxide, mousiness from certain lactic bacteria, filter taste from filter aids, filter pads, or filter mass, and metallic contamination.

For convenience the writer has used the following score card for judging experimental red dry wines.

Color	10
Clearness	5
Freedom from sediment	5
Aroma and bouquet	20
Total acidity	10
Volatile acidity	10
Tannin	10
Body and sugar content	10
General flavor	20
Total	100

For white wines and other wines the values assigned the various properties are changed to suit the class of wine. A simplified score card suitable for all wines is the following:

Flavor	50
Aroma and bouquet	30
Color and appearance	20
Total	100

The taster should taste a few wines each day, or at least two or three times a week, in order to "keep in trim." He should avoid highly flavored foods and distilled drinks and should keep in good physical condition. He cannot taste accurately a great many wines at a time; the writer prefers to taste not more than ten wines at a single sitting. Between wines one should rinse his mouth with water and, if there are many wines to be tasted, should occasionally eat a small piece of unbuttered French bread.

Analysis of Wines and Laboratory Control.—In the purchase and sale of wines, in internal revenue tax collection, in governmental regulation of the wine industry, and in the making and blending of wines, analyses are of the greatest importance.

The tax-collecting authorities are interested principally in the alcohol content of the wine. In the buying and selling of wines, alcohol, volatile acidity, sugar content, total acidity, and for red wines tannin content are the usual chemical determinations. In laboratory control of winemaking operations, the following determinations are of greatest value: volatile acidity, since it is a measure of soundness; sugar content, since the stability of dry wines and the flavor of sweet wines depend upon it; alcohol content, since dry wines must contain less than 14 per cent by volume and sweet wines not more than 21 per cent and since this informa-

tion is necessary in blending and other cellar treatment; total acidity, since its value must be known in order that blending or acidification may be conducted intelligently; tannin content of red wines, since the flavor of red wines depends in large measure on tannin content and since some types of red wines are made to definite tannin content; and the Balling degree of fortified wines, since "standard" fortified wines are made to certain Balling degrees, *e.g.*, standard Port is 6° Balling.

Methods of analysis are fully described in "Official and Tentative Methods of Agricultural Analysis" of the Association of Official Agricultural Chemists, Woodman's "Food Analysis," and in Cruess, Joslyn, and Saywell "Analysis of Wines and Other Fermented Fruit Products"; therefore, they will not be discussed here.

Microscopical examination of wine is of the greatest importance since it will often reveal the presence of spoilage bacteria before chemical analysis or taste indicates any deterioration and since it will prove whether or not observed cloudiness and sediment formation are due to microorganisms (see section on spoilage).

Interpretation of Analyses.—The interpretation of the analysis of a wine is dependent in great degree upon the experience of the person concerned and upon the use to which the analysis is to be put. For example, a wine maker may receive from his chemist the analysis of a 30,000-gal. tank of new red dry wine and observe that it contains 13.8 per cent alcohol, 0.72 per cent total acidity, 0.68 per cent of residual sugar, and 0.045 per cent volatile acidity. One can readily see that the fermentation has been sound but incomplete. The high alcohol content shows that the grapes contained an excessive amount of sugar, and in order that fermentation may again be resumed and completed, it will be necessary to dilute the wine with water or blend it with the new wine of low alcohol content. A dry red wine should contain less than 0.20 per cent unfermented sugar.

In another case a new dry white wine is found to contain 0.085 per cent volatile acidity, 12.5 per cent alcohol by volume, and 0.16 per cent sugar. The microscope shows a considerable number of long, slender rod bacteria. This wine should be pasteurized at once at 180 to 184°F. for 1 to 2 min.; cooled to room temperature; filtered brilliantly clear and given 100 to 150 p.p.m. of sulfur dioxide or an equivalent amount of potassium metabisulfite. The treatment destroys, removes, and prevents the growth of the spoilage bacteria.

Another red wine is found to contain 0.155 per cent volatile acidity and 12.3 per cent alcohol; it is free of lactic bacteria and, except for excessive volatile acidity, is normal in taste. Evidently, it has been attacked by acetic bacteria. It may be pasteurized; filtered; given 100 to 150 p.p.m. of sulphur dioxide, and blended with a bulk quality

wine of low volatile acidity in order to reduce the volatile acidity below the California legal limit of 0.120 gram per 100 cc.

Another wine contains 0.20 gram volatile acidity per 100 cc., 0.45 gram sugar per 100 cc., and 13 per cent alcohol. It has many long rod bacteria and a noticeable "lactic" taste. The wine is fit only for distillation for brandy for fortification of sweet wines. It is hopeless for use as wine.

Effect of Jerez Yeast on Volatile Acidity.—In recent experiments the writer has found that the volatile acidity of dry wines high in this constituent can be reduced by action of Jerez yeast grown as a film on the wine. Briefly, the procedure consists in adding to the wine sufficient sulfur dioxide or potassium metabisulfite to give a total sulfur dioxide content of 100 to 150 p.p.m. to prevent growth of vinegar bacteria and lactic bacteria. It is then placed in a tank or cask filled only two-thirds full. It is then heavily inoculated with Jerez film. The bung is left open except for a loose cotton plug. In a few months' time the excess acetic acid is destroyed and the flavor is greatly improved. However, the principal practical application of this procedure is in preventing spoiling by vinegar bacteria of wine undergoing the Spanish "flor" process for Sherry. It is not recommended as a means of salvaging vinegar-sour wines. Such should be converted into vinegar or used for distillation.

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CHAPTER XXXI

FROZEN-PACK FRUITS AND VEGETABLES

During the past few years the preservation of fruits and vegetables by freezing and their distribution in the frozen state have increased greatly. It is now the most important outlet for berries in the Pacific northwest. Until recently the method had not been adopted on an extensive commercial scale for vegetables; but at present the preservation of peas by freezing has become an important industry, and the frozen packing of corn and Lima beans is on the increase. In time it is possible that this method of distributing fruits and vegetables will attain the same relative importance that it has long enjoyed with respect to beef, mutton, poultry, and fishery products.

The industry has rather generally adopted the term "frozen pack" to describe the products, *e.g.*, "frozen-pack peas," etc., and the term "freezing preservation" to designate the process.

Frozen-pack fruits and vegetables very nearly approximate the fresh in color, flavor, and cooking quality. Thus, frozen-pack peas after cooking can scarcely be distinguished from the cooked fresh peas. Those who desire a more extensive presentation of the subject are referred to the book by D. K. Tressler and the other publications on page 713.

Not All Fruits and Vegetables Suitable.—Some fruits and vegetables lend themselves well to preservation by freezing storage, and their distribution in the frozen form appears economically feasible. In this category may be placed most of the important varieties of berries, avocados, persimmons, sour cherries, mangoes from the tropics, possibly several other fruits of delicate texture and flavor and relatively high price, green peas, corn on the cob, spinach, Lima beans, and possibly certain varieties of green pod beans.

On the other hand there appears to be little or no justification for the freezing storage of bananas, citrus fruits, pears, prunes of the drying varieties, apples, canning and drying varieties of peaches, pineapple, cut corn, tomatoes, pumpkin, and some other vegetables that are equally satisfactory as canned products.

Some fruits and vegetables may or may not become important for use in frozen pack. Apricots, for example, canned solid-pack style and preserved by heat are perfectly satisfactory for bakers', ice-cream makers' and preservers' use, as well as being inexpensive and convenient; yet

the frozen-pack, thoroughly ripe fruit in syrup is superior to the usual canned product in quality for dessert use. Its higher retail price, therefore, might not deter the purchaser. Peaches of delicate flavor and color, unsuited to canning but of especially high quality for dessert purposes (peaches and cream), might find favor in the high-price retail trade, where they might be preferred to the less costly canned peaches. Perhaps frozen-pack asparagus, owing to its excellent texture and flavor, might prove popular in spite of its relatively high retail price. Other examples could be given.

Distribution, a Limiting Factor.—At present probably the most serious obstacle to rapid expansion of this industry is that of the difficulty and cost of retail distribution. The major portion of frozen-pack fruits at present are sold to preservers, ice-cream makers, and bakers, who utilize them between fruit seasons for the same purposes as the fresh fruits. The most important market for frozen-pack vegetables is to hospitals, ocean liners, restaurants, hotels, and other large users of food products. However, the retail distribution of frozen-pack fruits and vegetables is very rapidly increasing.

Since the products must be kept frozen until delivery to the ultimate consumer, retail stores, such as groceries and fresh fruit markets, must make a heavy investment in refrigerating equipment and freezing storage space. This fact has been a serious deterrent to retail distribution.

However, it should be perfectly feasible and not unduly costly for the present large, central cold-storage warehouses located in all large centers of population to distribute the frozen products daily from their freezing storage vaults to the retail distributors. The distributors in turn would sell and deliver each day's delivery before it could deteriorate. Possibly, inexpensive large Thermos-bottle type containers of 10 gal. or greater capacity could be utilized to hold the products in the frozen condition several days. Marsh and Joslyn of this laboratory have found this procedure entirely satisfactory. Fairly inexpensive ice-cream dispensing cabinets can also be used.

It has also been proposed that frozen-pack products be delivered to householders by milk distributors with the morning's milk. Orders probably would be taken on the day preceding delivery.

Frozen foods are not sterile since freezing kills only relatively few of the microorganisms present. Therefore, after thawing and a consequent rise of temperature, these products spoil quickly. They should be kept frozen until delivery or should be used very shortly after thawing. It is for this reason that some means of maintaining the frozen products at a low temperature until delivered to the consumer is necessary.

Physical Changes Occurring during Freezing and Thawing.—The purpose of freezing storage is to retain to as great a degree as possible

the properties of the fresh fruit, vegetable, or other food product. However, during freezing and thawing certain irreversible changes occur that render the frozen and thawed product quite different in texture and general appearance to the fresh. There is usually considerable collapse of the tissues on thawing; the thawed product usually is rather limp, and considerable liquid is usually lost from the tissues as "drip liquid" on thawing and draining. The extent of these changes varies greatly with the character of the product. Thus some starchy vegetables such as peas, shelled green beans, and corn change, relatively, much less than certain other products such as tomatoes, lettuce, and cantaloupe. The starch evidently gives additional support to the cells.

Woodruff (*Bulletin* 168) has given a good summary of the changes that occur and the various theories offered in explanation thereof. He states that flabbiness is due to breaking down of the contents of the cells which formerly gave support to their walls. The loss of plant juices is not because of rupture of the cell walls but, he believes, because of the irreversible precipitation of cell contents liberating "bound water" and also water which was previously present in the vacuole; this water is not reabsorbed on thawing. He found that the amount of water lost through cell leakage is very similar to that lost through leakage caused by cooking, lost by placing the tissue in saturated salt or sugar solution, or lost when undergoing desiccation. Woodruff calls attention to the fact that tissues having very thick cell walls do not show as marked changes as those with thinner cell walls, owing to the fact that support of the tissues is largely maintained by the cell walls.

The following theories have been offered in explanation of the changes observed in plant and animal tissues on freezing and thawing. Classen believed that the injury is caused by puncturing of the cell walls by ice crystals. Sommerville in England and Sachs in Germany thought injury was due to too rapid thawing. Chandler, Maximov, Mollard, Matruchat, and Molisch independently have put forward the theory that injury is not due to cold directly but to ice formation. Desiccation by withdrawal of water into the intracellular spaces to form ice causes death of the cell. The plasma membrane is destroyed and plasmolysis occurs. Maximov believed the actual injury was caused by changes in the plasma colloids during ice formation. Chandler sums up the ice-formation theory by saying, "There can be no injury by cold without ice formation." A modification of the preceding theory is that death of the cell is caused by salting out of the protein fraction of the protoplasm owing to high salt concentration induced by withdrawal of water. The protoplasmic gel is thus destroyed. Another theory attributes death of the cell to precipitation of proteins owing to increase in hydrogen-ion concentration. Still another theory holds that injury to the protoplasm by cold is occasioned

by increase in viscosity of the protoplasm beyond the point where it can function.

Woodruff and also Joslyn and Marsh favor the ice-formation theory of Chandler, Maximov, and the other investigators mentioned on the preceding page. It appears to be the theory best supported by evidence and scientific opinion.

Freezing disorganizes the tissues, renders them permeable, and liberates enzymes. Consequently during thawing, certain enzymes, particularly oxidizing enzymes, often cause serious changes. Sliced fresh peaches, apricots, and pears darken very rapidly on thawing owing to oxidasic browning. For this reason such products may require treatment with sulfur dioxide or blanching to retard or inactivate oxidizing enzymes.

The extent of the physical changes occurring during freezing and thawing of fruits and vegetables was extensively studied by Joslyn and Marsh (*Bull.* 551, 1933). They gave particular attention to the "drip loss" on thawing, *i.e.*, the loss in weight owing to exuding and dripping away of tissue juices during draining of the thawed products for 24 hr.; as affected by rapidity of freezing, composition of the liquid surrounding the product while frozen, and other factors. Strawberries, packed with various proportions of dry sugar to fruit, lost from 19.4 to 44.2 per cent in weight on thawing after freezing storage of several months. Apricots lost 2 to 13.6 per cent. When packed in syrups, the losses were lower, although in several individual instances heavy loss in weight on draining occurred.

They observed that fruits and vegetables frozen quickly in carbon dioxide "snow" lost less liquid on thawing than when frozen at 0°F. in air. Thus peas frozen at 0°F. in air lost 8.4 per cent in weight on thawing, and those frozen in carbon dioxide snow at −110°F. lost 4.5 per cent. The figures for asparagus were 23.4 and 19.2 per cent; for string beans 14.5 and 8.2 per cent; strawberries 37.1 and 29.7 per cent; and apples, sliced, 1.03 and 0 per cent loss. Woodruff gives additional data for fruits indicating a somewhat smaller drip loss from fruits frozen in carbon dioxide "snow" ("dry ice") than those frozen slowly in air, presumably at 0°F. However, on subsequent cooking of frozen-pack vegetables there was little to no observable difference between the slow- and the quick-frozen products. Some vegetables blanched and packed in dilute brine before freezing actually gained in weight on thawing in Joslyn and Marsh's experiments.

Another change that occurs on freezing is expansion in volume. Whole fruits often burst on freezing; the same is true of shelled Lima beans. Barrels or glass jars of frozen-pack juices, crushed fruits, and other liquid or semiliquid products must not be filled completely, else

they may be burst by expansion of the contents on freezing. Joslyn and Marsh give the following increases in volume on freezing at 0 to 5°F.: water, 8.6 per cent; 20 per cent cane sugar syrup, 8.2 per cent; 40 per cent syrup, 5.2 per cent; 50 per cent, syrup 3.9 per cent; and 60 per cent syrup, no increase in volume.

Chemical and Enzymatic Changes.—Changes in color, flavor, texture, and odor of food products induced by enzyme action and by chemical change may occur before and during freezing, during storage, during thawing, and after thawing.

Certain fruits are prone to turn brown in color because of action of oxidizing enzymes plus atmospheric oxygen; this change is particularly rapid during and after thawing. Such fruits, packed without syrup, brown severely in freezing storage when stored in containers that are not airtight. Light treatment with dilute sulfur dioxide solution prevents such changes.

Berries and other fruits, stored without syrup in containers that admit air gradually, deteriorate in flavor, odor, and color, the deterioration being more rapid at temperatures of 20 to 25°F. than at −5 to 10°F. Such fruits cannot be treated with sulfur dioxide or blanched without completely changing their character. Probably enzymes are involved.

Unblanched vegetables deteriorate rapidly in color, flavor, and odor even when stored at −5°F. They develop a hay-like odor and flavor and their initial green color changes toward the yellow, eventually becoming yellow, *i.e.*, when later cooked for eating. These changes have been definitely proved by Joslyn and Marsh, and by Diehl and his associates to be due to enzyme action. Undoubtedly some of the deterioration is oxidative in nature, but it is equally probable that other enzymes than the oxidases are also involved.

Diehl and associates found that catalase activity, judged qualitatively by addition of hydrogen peroxide to a crushed sample of the blanched vegetable, was a rough index of the amount of deterioration to be expected during storage. Thus, when peas and certain other vegetables were blanched sufficiently in steam or hot water to inactivate catalase, they could be expected to keep reasonably well.

Subsequently, however, Arighi, Joslyn, and Marsh found that considerably higher temperatures or considerably longer periods at lower temperatures than required to inactivate catalase were required to prevent undesirable changes during freezing storage of peas and spinach grown in California. They used a storage temperature of 0°F. They found also that the acetaldehyde content of the blanched peas closely paralleled their keeping quality but that no such relationship existed with spinach. They reported that peas blanched 2 min. at 60°C. (140°F.) contained a fairly active catalase and deteriorated severely in flavor and

color; those blanched 2 min. at 65°C. (149°F.) were free of catalase, but they nevertheless deteriorated markedly in color and flavor; the same was true of those blanched 2 min. at 67.5°C. (153.5°F.). Those blanched 2 min. at 70 and 75°C. (158 and 167°F.) were free of catalase but somewhat inferior in flavor and color, after freezing storage, to those blanched at 77.5°C. (171.5°F.). The best quality was attained at 80 and 85°C. (176 and 185°F.). At 90°C. (194°F.) the texture was too soft and the skins rather tough; these defects were more evident at 95 and 100°C., evidently owing to overcooking.

Vegetables even when heavily blanched to destroy all enzymes lose their green color, and acquire disagreeable odors and flavors when stored for a long period in freezing storage in containers that admit air freely. Evidently in this instance simple oxidation is involved.

There is evidence that pectic enzymes of berries cause some hydrolysis of pectin. Invertase is also active during and after thawing, causing inversion of sucrose.

Microbiology of Frozen Foods.—Microorganisms are of concern to frozen-food packers and consumers for two reasons; they may cause deterioration in quality and even complete spoilage, or they may render the food dangerous to health.

If one consider the first of these roles, it may be stated that organisms may develop before the product has become frozen; a few forms are able to develop in freezing storage at certain temperatures; and they may grow in the product after thawing. In California in the early days of freezing storage, considerable spinach packed hot in large fiberboard boxes spoiled before it attained freezing temperature. Although the containers had been placed at a freezing temperature, cold penetration was so slow in the large masses of solid-pack blanched leaves that microorganisms multiplied and caused spoilage before the centers of the packages attained a temperature that would inhibit growth. In order to prevent such spoilage, the product should be frozen in shallow trays or at least chilled nearly to freezing before packing in large containers; or it should be packed in small containers. It is also essential that the packages, even small ones, be stacked in the freezing room in such manner that air can circulate freely between them; or they should be frozen in some form of machine-type freezer.

Peas deteriorate rapidly after shelling if allowed to stand too long before blanching and freezing. Spoilage can also occur rather rapidly after blanching if the peas are allowed to stand for a protracted period at room temperature. Under normal operating conditions, however, the peas are handled without delay from the sheller to the freezing room.

At one time it was generally assumed that there was no multiplication of microorganisms in frozen foods and that, as long as the product

remained frozen, deterioration through microbial activity could not occur. However, Berry reports growth of a Cladosporium sp. at −2°C. (28.4°F.); of an Oïdium sp., and of a Torula yeast at −4°C. (24.8°F.). Tanner states that there is some evidence that certain psychrophilic bacteria may grow at −10°C. to −20°C. (14°F. to −4°F.). In this connection Diehl, Pentzer, Berry, and Asbury state that certain molds may grow slowly at about −6.6°C. (20°F.) and some bacteria at −4°C. (25°F.). They recommend that storage temperatures much in excess of 15°F. (−9.5°C.) should not be employed. Also the lower the storage temperature the slower is deterioration caused by enzyme activity and chemical change.

A great deal of research has been conducted on the problem of effect of freezing storage on *Clostridium botulinum*, typhoid bacilli, cholera bacilli, and on other toxic or disease-producing bacteria. In general, freezing kills many, but not all these organisms. In fact, freezing storage preserves many of them, just as it preserves the food product. Data have been reported showing that molds yeasts and bacteria have lived for several years in frozen foods. They appear to survive better at the lowest temperatures used than at temperatures only slightly below freezing.

Wallace and Park found that the spores and the toxin of *Cl. botulinum* survived freezing storage with no appreciable injury for at least 1 year; Straka and James obtained similar results.

Tanner cites an outbreak of typhoid at Yessy, reported by Lascu, from ice that had been frozen for 8 months. It has been found that typhoid bacilli will live in ice cream for more than 2 years. Wallace and Crouch found that a number of other pathogenic bacteria also survive for long periods in ice cream.

These various findings prove that pathogenic bacteria, if present in the food product, can survive freezing storage and, if the product is consumed without further cooking, can infect the consumer.

Cl. botulinum does not grow and produce toxin during freezing storage; but if the foods infected with it are allowed to thaw and to stand at room temperature for a sufficient time, toxin formation may ensue. Wallace and Park inoculated cherries, strawberries, raspberries, string beans, carrots, and peas with detoxified spores of *Cl. botulinum;* stored them at −16°C. (3.2°F.) for 2 weeks to 12 months; at intervals removed containers of the frozen products; allowed them to stand 3, 6, and 10 days; and fed small amounts to guinea pigs. The cherries remained nontoxic; toxin was produced once in strawberries and twice in raspberries. Toxin was produced in a number of samples of each of the vegetables; in several cases in 3 days' storage at room temperature. Also some of the samples of vegetables remained nontoxic even after 10 days at room temperature.

In commercial practice contamination with the spores of this organism would be much lower than in the samples heavily inoculated by Wallace and Park or by Straka and James; and probably in most cases the organism would be absent. Nevertheless, there is possibly a real danger in allowing frozen vegetables to thaw and stand several days before use. In one case observed in San Francisco frozen-pack peas delivered to a restaurant were reported spoiled and unfit for food. Investigation by Marsh and Joslyn showed that the delivery company had allowed the frozen peas received by it from the cold-storage warehouse to thaw and stand several days; the peas were then again frozen and delivered to the restaurant. Needless to say the product was completely spoiled.

It is therefore essential to maintain frozen-pack foods in the frozen state until received by the consumer, and he or she in turn must use them very soon after thawing.

On the other hand since frozen-pack vegetables are, or at least should be, cooked before serving, the health hazard is at most remote.

Diehl and associates found in some cases considerable increase in numbers of yeast cells in frozen-pack berries in 50-gal. barrels, owing to extremely slow cooling of the berries near the center of the container. They recommend precooling of the berries and sugar at about 32°F. before packing and also the establishment of maximum limits for numbers of yeast cells and mold present in frozen-pack fruits, as determined by the general Howard technique. Both recommendations are very worthy ones.

Containers.—It has been found that adverse chemical, physical, and enzymatic changes proceed at a slower rate in the frozen products when packed in hermetically sealed, airtight containers. In this regard the vacuum-sealed container is superior to that sealed in air. Enamel-lined tin cans for berries and other colored fruits are preferable to plain tin as they affect the color less. Key-opener, enamel-lined cans holding about 1 lb. of berries and sugar were used successfully in the Pacific northwest at one time. They were sealed under vacuum. The principal objection to the airtight container is the danger that the consumer will assume that the contents are nonperishable and may on that account allow the product to stand at room temperature with resulting spoilage. If the product is a nonacid vegetable, it may under such conditions become toxic. However, if the can bears on the label in large type some such advice as: "Perishable—Use at once after Thawing" there should be little danger in using such containers. Large friction-top, enamel-lined containers such as those used for frozen eggs are suitable for packing frozen-pack fruits and vegetables for use by preservers, hotels, and other large consumers. These cans are usually of 30 lb. capacity, and commonly used for broken eggs preserved by freezing.

Small friction cans are also available for the household trade. Since they are nearly airtight, they prevent absorption of off odors and flavors and because of their convenience are to be rather highly recommended for frozen-pack foods.

Paraffined cardboard cups and "tubs" are in common use for frozen-pack foods and have proved fairly satisfactory, particularly for foods packed in brine or syrup. The 1-lb. size is the most popular. It is usually packed 24 to the case. The covers slip into a groove near the top of the containers in some styles, and in others the top is crimped into place by rolls in much the same manner as in the sealing of tin cans. The principal objection to these containers is that they permit considerable oxidation of such products as apricots, dry-pack vegetables, apples, peaches, and pears. They may also admit off odors and flavors from the storage room. They are inexpensive, convenient, and light in weight.

The largest packer of frozen foods for the retail market, General Foods, uses small, paraffin impregnated cartons which are lined with a late[illegible] inner liner. The products are packed without liquid. This [illegible]orm [illegible]ackage is convenient for freezing in the continuous freezers [illegible]sed by that company.

Peas and other vegetables have been packed also in paraffin paper-lined fiberboard boxes, the vegetables being first frozen in air in a sharp freezing room or rapid freezer and packed in frozen condition without liquid in the boxes which are sealed and stored at once at or below 15°F. Glass containers also can be used, although heavier and usually more costly than tin or paper containers.

Theoretically, the vacuum-sealed airtight tin container is preferable to paper-container cartons, friction-top cans, and other containers that admit air to and permit evaporation of moisture from the product. For many products the "not-airtight" containers are quite satisfactory, particularly if after freezing they are packed in lined, tightly sealed cases. There is then less tendency for evaporation of moisture and much less opportunity for absorption of cold-storage odors and flavors.

In the Pacific northwest most of the berries for bakers' and preservers' use are packed in paraffin-lined spruce barrels of various sizes, the 50-gal. size predominating. Berries usually are packed in these with dry sugar. One of the objections to these containers is the slow freezing of the contents, owing to the slow penetration of heat or "cold" through the wood and to the great distance to the center of the container. Hence the contents are often at a temperature that will permit growth of yeasts or molds for 24 hr. or longer. A second objection is that once the barrel of berries is opened the contents must be used soon since the berries near the surface in the opened barrel rapidly deteriorate in flavor and color through

oxidation. Barrels are convenient to fill, store, and ship and are relatively inexpensive. The writer would prefer the 30-lb. egg tin or similar container to barrels since it is not costly, it may be used several times, its contents freeze quickly, and it is convenient to handle.

Blanching (Scalding).—At present fruits for frozen pack are not blanched before freezing. Berries would soften badly and blanching is probably of no value for them. On the other hand, sliced or halved peaches, pears, and apricots and sliced or quartered apples would probably be benefited in quality for freezing by a preliminary mild blanching sufficient to inactivate oxidizing enzymes, since it would inhibit browning and development of undesirable flavors, particularly during, and subsequent to, thawing. From experiments in this laboratory blanching in water at 180 to 185°F. for 3 to 10 min., depending on the size of the pieces, would inactivate the enzymes without materially affecting the fresh flavor and texture of the fruits.

All vegetables for frozen pack should be blanched before freezing in order to inactivate enzymes that cause undesirable chang in odor, taste, and color. As stated in the section on enzymes, unblanched vegetables acquire during freezing storage a disagreeable hay-like odor and flavor and deteriorate in color; also some unblanched vegetables become tough in storage. As mentioned elsewhere, Diehl and associates have stated that, if blanching is sufficient to destroy catalase, the vegetables will keep satisfactorily in freezing storage. Joslyn, Marsh, and Arighi, however, are convinced from their experiments, particularly with peas and spinach, that a considerably more severe blanching is necessary, owing to the fact that other enzymes responsible for undesirable changes are considerably more difficult to inactivate by heat than is catalase. They decided that blanching at 85 to 90°C. gave products of better flavor, odor, and texture than when blanched at 95 to 100°C.

Smart and Brunstetter found that blanching of Lima beans at 212°F. for 3 min. gave a more satisfactory product than blanching a longer or shorter period at 212°F. or blanching at 190°F.

Probably, for average commercial conditions, blanching at the boiling point either in steam or in boiling water will prove more practicable than blanching at lower temperatures. Since steam removes less of the water soluble materials than does water, perhaps it should be recommended in preference to boiling water for vegetables to be packed without liquid. The period of heating will vary considerably with the kind of vegetable and its previous preparation; thus corn on the cob will require a much longer period than peas (see directions for the individual vegetables).

In addition to inhibiting enzyme action and thus stabilizing odor, flavor, and color, blanching wilts the vegetable and decreases its volume so that it may be packed more conveniently and efficiently.

Packing with and without Liquid.—At present considerably more fruits and vegetables are packed without syrup or brine than with these liquids. Experiments conducted at the University of California in 1918 by Overholser, Bjarnason, and the writer and repeated on a more extensive scale later by Joslyn, Marsh, and others showed that berries and other fruits retain their color, flavor, and texture better when packed in syrup than when packed with sugar or with no addition.

It has been our experience in this laboratory that for fruits that darken rapidly, such as apricots, white grapes, peaches, and pears, the addition of syrup is practically necessary. The darkening can also be prevented by use of sulfur dioxide or preliminary blanching. Berries,

Fig. 108.—Small containers suitable for frozen-pack foods.

however, behave quite satisfactorily when packed with dry sugar. Peas, corn, spinach, and string beans are satisfactory packed dry without liquid, although Diehl and associates of the U. S. Department of Agriculture and Joslyn and Marsh of this laboratory have found the quality to be somewhat better when frozen in 2 per cent salt brine. Asparagus, owing to its tendency to collapse and become stringy, was considerably more satisfactory in brine.

Commercial handlers and large users of frozen-pack foods prefer the dry-pack because of its lower weight and convenience; it is not necessary to thaw a large solidly frozen mass. The dry-pack products are much more easily removed from the containers. The shipping weight is, of course, also much lower. In general, however, they deteriorate more rapidly in storage than do the same foods packed in syrup or brine.

Some products, such as avocado flesh for use in ice cream, persimmon for fountain and ice-cream use, and certain other soft fruits are most satisfactory for freezing storage when crushed and mixed with the requisite amount of sugar before freezing.

The procedure will vary with the product, the demands of the trade, and to a great extent the preference of the packer.

Rates of Cooling and Freezing.—Diehl, Magness, Gross, and Bonney determined the rates of cooling of berries packed with sugar under practical industrial conditions in the Pacific northwest. Resistance thermometers were inserted to the center of the containers; they were also inserted 4 to 6 in. from the bottom and 4 to 6 in. from the top after the barrels were filled. Naturally, cooling was more rapid in the latter two positions than at the center. In one experiment the freezing room was at 14°F.; Marshall strawberries were packed with dry sugar as a 2 + 1 pack, *i.e.*, 2 lb. of berries to 1 of sugar, in a 50-gal. barrel, the berries and sugar being at about 61°F. when packed. Nine hours elapsed before any cooling occurred at the center of the barrel. At 24 hr. the temperature at the center was 53°F.; at 48 hr. it was 42°F.; and at 72 hr., 34°F. These conditions would have been considered very favorable for commercial packing of berries; yet, the fruit was at a temperature favorable to the growth of yeast for more than 48 hr.

In another experiment 50 gal. of 2 + 1 Marshall strawberries were placed in rooms at 0°F., 15°F., and 30°F. At 0°F. the center of the barrel reached 40°F. in 1½ days; at 15°F. in 2 days; and at 30°F. in 3½ days. Similar results were obtained with other varieties of berries. Even at 0°F. the berries remained for over 1½ days at temperatures which would permit yeast growth and fermentation.

Because of this very slow cooling in these large barrels with considerable resultant spoiling, it has been customary to place a block of ice in the center of the barrel of berries. While this hastens cooling, it dilutes the pack, and the addition of ice must be declared on the label.

Accordingly, in several of Diehl's experiments, berries were precooled in shallow crates at 32 to 34°F. for 18 hr., removed, and packed with sugar in 50-gal. barrels as a 2 + 1 pack. The contents of the barrels were at 36 to 42°F. when rolled to the freezing room, as compared with 60 to 70°F. for berries packed without precooling. Consequently the precooled berries were at a much more favorable temperature to resist fermentation. About 2½ days' cooling at 15°F. was required to chill the contents of the nonprecooled barrel to the initial temperature of the precooled fruit. Therefore, it can be seen that precooling should be used for berries to be barreled; although most plants are not well prepared to conduct this extra operation. This practice would prevent practically all danger of condemnation of barreled berries by state or federal food authorities on the basis of high yeast count.

Joslyn and Marsh (*Bull.* 551) made numerous measurements upon the rate of cooling of various food products in various sizes and types of containers, using thermocouples placed at approximately the centers of

containers and connected to a sensitive potentiometer in order to follow temperature changes. One interesting finding was that cane sugar cooled more rapidly than did water and continued cooling without interruption until the temperature of the freezing room (about 4°F.) was attained. Water and light syrups cooled steadily until they began to freeze, then remained at a constant temperature in No. 10 cans for 20 to 24 hr. because freezing was occurring and because, after freezing had occurred, the ice conducted heat very slowly. Syrup of 70° Brix apparently did not freeze, and its cooling curve paralleled that of dry sugar. Heavy syrups cooled more rapidly than light syrups; quite the reverse of rates of heating of cans of syrup in steam. In the latter case heat is carried by convection principally, whereas during cooling it is conducted almost wholly by conduction, a much slower process than convection.

They demonstrated that cooling of cans or paper cups packed in fiberboard or wooden cases was very much slower than of the same small containers standing individually in the freezing room so that the cold air could circulate freely between them. From 10 to 27½ hr. time was required for 1-lb. flat cans of fruit pulp to reach the freezing point of the pulp when packed in various types of fiber and wooden cases. Cans in the upper corners cooled most rapidly; those in the lower center position, the most slowly; the former cooled about twice as rapidly as the latter. When practicable, it is advisable to cool the small containers before packing them in cases.

They found that the cooling of various products in small containers was about five times as fast in solid carbon dioxide at −110°F. as in air at 2°F. The "freezing period" (period during which the temperature remained constant during and after ice formation) was very much shorter in the solid carbon dioxide than in air at 2°F.

While rates of cooling varied somewhat with the nature of the product, the differences were very much less than those encountered in rates of heating of different canned products, such for example as peas and cream-style corn, because, as stated above, cooling in freezing storage occurs principally by conduction. Since most fruits and vegetables consist chiefly of water, their rates of heat conduction will be similar—and similar as well to that of water.

Joslyn and Marsh also followed the rates of thawing, *i.e.*, of temperature rise on removal of the frozen products to room temperature and rates of melting after the melting temperatures were attained. The "thawing curves" were more or less inverse to the corresponding "cooling curves." There was a characteristic rise to the melting point; a period of several hours at a constant temperature during melting; and then a slow rise to room temperature.

Methods of Freezing.—While freezing should be as rapid as possible, in order to forestall undesirable enzymatic changes, the writer agrees with Joslyn, Diehl, and others that probably this requirement has been overemphasized by some. The work of Joslyn, Marsh, Diehl, Berry, and others has amply shown that fruits and vegetables packed in small containers or spread on trays or shallow pans freeze sufficiently rapidly at 0°F. for all practical purposes.

The usual practice is to place the packages in the freezing room at or below 0°F. arranging them so that air may circulate freely; or

Fig. 109.—Sugar and fruit mixing equipment for frozen-pack berries.

better still, forced air circulation may be used to hasten freezing. Quick freezers using refrigerated air below 0°F and circulated by fan at fairly high velocity are now in general use. They are quite satisfactory for most products. Some products to be packed without syrup or brine in rather large cans or cartons are frozen in this manner on trays before packing in order to minimize deterioration and to give a "free-flowing" frozen product.

One large producer of frozen-pack foods uses a continuous freezing machine through which cartons containing the food pass between metal belts chilled by cold brine. The cartons of frozen products are packed in cases and are placed at once in freezing storage. In another type of continuous freezer, used for fish, the prepared fish pass through sprays of cold brine that freezes the product very quickly; and this system would be suitable for freezing fruits if packed in sealed containers such as cans, or if suitable modification of applying a freezing medium adaptable to fruits were devised.

Experimentally, fruits and vegetables have been very quickly frozen by contact with solid carbon dioxide, or by contact with thin metal vessels containing solid carbon dioxide. Insofar as the writer is aware this refrigerant has not been applied industrially for quick freezing of foods.

Storage Temperatures.—Diehl and others recommend that storage temperatures not above 15°F. be used because at higher temperatures certain microorganisms may multiply, whereas at or below 15°F. they decrease in numbers, and because the lower the temperature the less is chemical and enzyme action. Diehl and Berry report that scalded peas, asparagus, Lima beans, corn, spinach, cauliflower, and string beans retained their color and general quality more satisfactorily at 5°F. than when stored at 15°F. They recommend that best industrial practice calls for a storage temperature of about 0°F. (−17.8°C.). Caldwell and associates of the Bureau of Plant Industry of the U. S. Department of Agriculture made similar observations with various vegetables.

Therefore, it appears that, in order to eliminate danger of growth of certain microorganisms, a storage temperature of not above 15°F. should be used; and in order to reduce enzymic and chemical action to a minimum, the storage temperature should be in the neighborhood of 0°F.

Use of Sulfur Dioxide in Frozen-pack Fruits.—Frozen fruits for use in pies, jams and other cooked products may be treated with dilute sulfur dioxide solution to prevent their darkening during storage and after thawing, without impairing their flavor for these purposes. Joslyn and Mrak report that dipping sliced apples in a 0.40 per cent solution of sulfur dioxide for a few minutes (2 to 5) effectively prevented browning during storage and thawing. Pies made from such fruits were very low in sulfur dioxide content, and most persons could detect no taste of sulfur dioxide. They found sodium bisulfite solution equally effective, more convenient, and not unduly costly. They recommended it in preference to plain sulfur dioxide solution. The addition of 2 per cent of salt to the sulfur dioxide dipping solution increases its effectiveness somewhat.

They recommend the following procedure: Prepare a sodium bisulfite solution equivalent to about 5,000 p.p.m. of sulfur dioxide, or a pure sulfur dioxide solution of about that concentration. To prepare such a solution add about 1¼ lb. of c.p. sodium bisulfite to each 20 gal. of water. Potassium metabisulfite may be used instead of the bisulfite. Use only paraffined wood, stainless steel, or other material not attacked by the sulfur dioxide.

Peel and core washed apples; discharge the whole peeled fruit into the sulfite or sulfur dioxide solution. Remove, slice, and discharge the sliced fruit into a fresh solution of sulfite or sulfur dioxide containing about 5,000 p.p.m. sulfur dioxide (0.5 per cent). Leave 2 to 5 min. Drain

and pack in 1 gal. slip-over top cans, paraffin-paper-lined cartons, or 30-lb. egg cans. The cans must be enamel lined. Store at 0 to 10°F. until needed, and remove as required. It is recommended that the fruit be thawed at 40 to 50°F.

Apricots are halved, pitted, quartered, and dipped in the solution for about 5 min. or somewhat longer. Peaches are halved and pitted, lye peeled (see Chap. VI), quartered or sliced, and dipped 5 min. or longer in the sulfur dioxide solution. The treated apricots and peaches are packed as described for apples.

Fruits treated as described above may also be packed in wooden boxes lined with waxed paper. In this case, as sulfur dioxide will escape more rapidly than from cans, the sulfur dioxide treatment should be somewhat longer than given above.

Packages of fruits treated with sulfur dioxide or sulfite must be suitably labeled to indicate that they have been so treated, in order to conform with state and federal food regulations.

DIRECTIONS FOR FRUITS

The following paragraphs have been prepared to serve as working directions for the preparation and freezing of various fruits. They take into account the various principles and practices discussed earlier in this chapter.

Apples.—Prepare as for canning. Then store in one-half of 1 per cent sulfurous acid solution for about 10 min. Drain. Pack in paper-lined boxes. Freeze.

Apricots.—Use only well-ripened fruit. The Blenheim, Tilton, and Royal varieties are satisfactory. Sort, pit, and wash. Airtight containers are preferred in order to prevent oxidation. Cover with a 40 to 50° Balling cane or beet sugar syrup. Vacuum sealing is recommended.

If to be used in bakery products or preserves, an alternative method may be used as follows. Dip the halved or quartered fruit in a 1.0 per cent solution of sodium bisulfite or a 0.5 per cent pure sulfur dioxide solution for about 10 min.; drain and pack without syrup in paraffined cartons or other suitable containers, preferably airtight. The solution used for dipping should contain about 5,000 p.p.m. (about 0.5 per cent) of sulfur dioxide, or its equivalent in sodium bisulfite.

Probably the most satisfactory procedure is to dip in sulfur dioxide as suggested above and then pack in a syrup of 40 to 50° Balling.

An excellent method consists in dipping in dilute sulfur dioxide solution followed by packing with 1 part of dry sugar to 3 or 4 parts of fruit.

Avocados.—This fruit has never been canned successfully; but it behaves well in freezing storage. Use table-ripe fruit. Peel by hand.

Halve the fruit, and remove the pit. Grind coarsely, and add about 1 lb. of sugar to each 3 lb. of fruit. Stir until the sugar is dissolved. Pack in cans or other airtight containers. Seal to exclude air. This fruit is excellent for use in ice cream.

Cherries.—Sour cherries are pitted and usually packed with 1 part of dry sugar to 3 to 4 parts of cherries in barrels or large slip-over top cans. They are used by preservers and pie bakers.

Sweet cherries are, in general, more satisfactory for canning than for freezing storage.

Figs.—Use varieties of rich flavor and tender skin such as the Mission and Kadota varieties. They should be table ripe, considerably riper than for canning or shipping. Airtight containers are strongly recommended in order to prevent off flavors induced by oxidation. Pack whole in a 35 to 40° Balling cane or beet sugar syrup. Or prepare by slicing and then pack with 1 part of sugar to 3 of sliced fruit. This product is excellent served as a dessert with cream. A short dip in dilute sulfur dioxide solution helps to prevent changes in flavor of sliced figs.

Grapes.—While grapes can be frozen fairly satisfactorily in syrup and on thawing, rinsing, and draining are edible and retain the fresh grape flavor, they are rather unsatisfactory in texture, resembling small rubber bags filled with juice. After thawing they rapidly oxidize. The writer sees no occasion for freezing them, other than, perhaps, for the use of bakers. The Thompson Seedless variety could be packed in light syrup in 30-lb. egg tins for that trade. For the winter fresh-grape trade, grapes, particularly the Almeria (Ohanez) and Emperor varieties, are much more satisfactory packed in cork dust or redwood sawdust in small kegs at 32°F. In that condition they keep well until midwinter.

Mangoes.—This fruit is very popular in the tropics and is not grown commercially in continental United States. Its importation from Mexico and elsewhere is prohibited because it is a carrier of the dreaded Mediterranean fruit fly. It changes adversely in flavor when heated and is, therefore, not very satisfactory when canned.

Experiments conducted by A. Valenzuela of the Philippine Bureau of Science have shown that it behaves well in frozen pack. Freezing destroys the eggs and larvae of the fruit fly; hence freezing should be worthy of consideration as a means of making this popular fruit available to Americans. It is recommended that the ripe fruit be peeled, pitted, sliced, and frozen at once in syrup of 25 to 40° Balling in airtight containers.

Nectarines.—Procedure is similar to that for apricots.

Olives.—Pickled ripe olives may be preserved successfully by freezing storage, as our experiments and those of Diehl have demonstrated. However, they are of superior texture and of approximately as good flavor

when canned and sterilized by heat in the usual manner. There is little justification for the freezing storage of this fruit.

Peaches.—Peaches vary greatly in suitability for freezing storage, according to variety. Freestones are usually preferable to canning varieties of clingstones. Of the former the J. H. Hale, Elberta, and Late Crawford are quite satisfactory; the Lovell and Solway are less so. The Muir freestone is unsatisfactory because it is mealy and "dry" in texture. Of the canning clingstones the Tuscan and the more highly flavored Midsummer varieties are preferable to the Philipps Cling and similar clings of tough texture and of poor flavor.

Use fruit that is thoroughly table-ripe, fresh, and free of bruises. Cut in half and pit. Lye peel or peel with steam as described in Chap. VI for canning. After washing to remove lye, rinse in 0.5 per cent citric acid solution to neutralize traces of lye. Pack as directed for apricots. If sliced, it is recommended that they be packed immediately in syrup to prevent browning or that they be treated with sulfur dioxide as described for apricots and packed with 1 part of sugar to 4 of fruit.

There appears to this writer little reason for freezing storage of canning varieties of peaches, since the canned products are so satisfactory. On the other hand, those of delicate flavor and texture are much more satisfactory frozen than canned.

Pears.—Not recommended for freezing storage since the canned product is superior to the frozen for most purposes.

Persimmons.—Like avocados, persimmons cannot be canned successfully and are not satisfactory for use in jams or preserves. A very satisfactory frozen-pack product is made as follows: The soft ripe fruit is converted into a heavy purée by rubbing through a screen of fairly fine mesh. The screen must be of copper, nickel, monel metal or other metal not attacked by the fruit; iron and galvanized iron cannot be used.

Sugar is added, 1 part to 3 to 4 of fruit, and the sugar dissolved by stirring. The mixture is packed at once in 30-lb. egg tins or smaller air-tight containers and frozen at 0°F. or lower. It is used in ice cream and fountain drinks made with milk, such as malted milks and milk shakes. It is also a very pleasing frozen dessert when served with whipped cream.

Pineapple.—Experiments in this laboratory have shown that fresh sliced pineapple may be preserved satisfactorily for about 6 months at 0°F. in a syrup of 25 to 40° Balling; after one year's storage some of our samples had acquired a distinctly off flavor. Canned pineapple and pineapple juice are of such excellent quality that there appears to be no urgent need for freezing storage of this fruit or its juice.

Plums and Prunes.—There is no great need for frozen-pack plums and prunes, although they are suitable for use in preparing jams, jellies, and butters commercially. In our experiments the thoroughly ripe

fruit was lightly crushed; packed solid-pack style in large cans and barrels; frozen at 0 to 10°F. and stored at this temperature range for more than a year with very good results. Egg tins of 30-lb. size also would be suitable containers. It is doubtful whether these fruits in frozen pack would find favor in the retail trade.

Fruit Juices.—Our experiments have shown that most fruit juices may be preserved for long periods in the frozen condition in airtight containers. Citrus juices, however, should first be deaerated, flash pasteurized at about 190°F., and sealed in an atmosphere of inert gas. Apple juice should be deaerated and flash pasteurized at about 190°F. to inactivate oxidasic enzymes, and thus check browning. The juices should be packed in enamel-lined cans or in glass as they acquire off flavors in paraffined paper containers. Storage should be at 0°F. Joslyn and Marsh have devised satisfactory procedures for most juices.

Whether or not juices will be preserved commercially by freezing storage is largely a question of cost to the consumer since the frozen juices must compete with those pasteurized in cans or bottles. It is doubtful whether the frozen-pack juices can compete in price with the canned and bottled; and their flavor, color, aroma, and general quality in most cases are not sufficiently superior, in the writer's estimation, to induce the average consumer to pay a higher price.

Strawberries.—Berries will be considered together, taking strawberries as the example. This is the most important fruit used for frozen pack. There are two markets for the product: one of the large users, such as preservers, ice-cream makers, and bakers, who desire the berries to be packed in barrels or in large tin containers; the second market, at present very limited, is to the retail trade, where small containers are desired.

Diehl recommends that firm varieties of deep color, firm texture, and rich flavor be used. They should be picked fully colored and firm ripe. They are hulled and washed and, if to be packed in barrels, should be precooled for 24 hr. in shallow pans or trays at about 32°F. The sugar used should also be precooled. The fruit and sugar are then packed into barrels or enamel-lined 30-lb. egg tins with dry sugar, the berries and sugar being mixed as the container is filled. Care must be taken to see that the sugar does not sift to the bottom of the container and there fail to dissolve. It may be necessary to upend the barrels to prevent that condition. A head space of 3 to 4 in. is allowed in the barrels for expansion during freezing. The ratio of sugar to fruit will vary with the desires of the purchaser. The usual ratios are 2 + 1, 3 + 1 and 4 + 1, *i.e.*, 2 of fruit to 1 of sugar, 3 of fruit to 1 of sugar, and 4 of fruit to 1 of sugar. Some are packed without sugar but are not nearly so satisfactory as the sugar-packed fruit. The total net contents of a 50-gal. barrel

of berries and sugar varies from about 400 to 410 lb. for the 4 + 1 pack to about 450 lb. for the 2 + 1 pack.

In actual practice the berries are usually not precooled before barreling, consequently some growth of yeasts may occur before the contents attain a freezing temperature. Usually the barreling stations are in or near the fields, and the barreled berries are transported a considerable distance to the freezing room. Freezing should be at 0°F. or lower and storage at or below 15°F.

For the retail trade the berries are usually packed in small cartons lined with waterproof waxed paper or parchment or in paraffined cups. Flavor, color, and aroma, however, are better retained in airtight containers and still better in vacuum-sealed airtight cans or jars. Texture and flavor are better retained in syrup than in the dry-sugar pack, although the consumer must wait longer for thawing of the syrup than of the sugar pack. The small containers are first frozen at 0°F. in air in a sharp freezing room or by patented continuous rapid freezers. After freezing they are packed in fiberboard cases and stored at 15°F. or lower.

Raspberries.—The procedure is essentially the same as described for strawberries.

Loganberries and Blackberries.—These are usually barreled for the preserving trade and are handled as described for strawberries. Blackberries must be not only deep black in color but also thoroughly ripe, otherwise they will turn red in color on freezing.

Youngberries, Boysen Berries, and Related Berries.—These are satisfactory either for barreling or for packing in retail-size containers as described for strawberries.

Cranberries.—These withstand freezing storage well. Pack the sorted and washed berries in a 50° Balling syrup. Airtight containers are not necessary. Diehl reports that cranberries do not keep well unless packed in syrup.

DIRECTIONS FOR VEGETABLES

The commercial freezing storage of vegetables and the distribution of them are still in the developmental stages, and while the more important basic requirements for their successful freezing and storage are known, it is probable that changes and marked improvements will ensue as a result of further research and commercial experience. The following recommendations are based on the best existing knowledge and best industrial practice; which in turn are the outcome of the research of H. C. Diehl, D. K. Tressler, M. A. Joslyn, G. L. Marsh, Jas. Berry, J. S. Caldwell and others. See references on pages 713 to 715.

Joslyn and Marsh and others have found that vegetables retain their texture more favorably and lose less weight on thawing and draining if

packed in brine; however, thawing of this pack is very slow. Hence housewives will probably prefer the dry-packed products. Large users such as hotels, passenger steamers, and others object to the brine pack because of its extra weight and inconvenience of handling and thawing.

Asparagus.—Green asparagus is probably to be preferred to the white for freezing storage, owing to its richer flavor and popular preference for the green color in fresh asparagus. Blanch 2 to 3 min. in boiling water or live steam and chill thoroughly in cold water. Pack in suitable containers, such as No. 10 tin cans for large users or in smaller cans or cartons for the retail trade, without brine. Seal and freeze at once at as low a temperature as possible. Asparagus sometimes absorbs off flavors and deteriorates in flavor in loose containers; hence the recommendation that tight containers be used.

While there is somewhat less shrinkage of the asparagus packed in a 2 per cent salt brine, there is practically no difference in appearance or texture between the dry-packed and brine-packed products after cooking the thawed products.

For success the asparagus must be fresh, preferably it should be frozen within 5 or 6 hr. after cutting, as it rapidly toughens, becomes stringy, and acquires a bitter taste on standing at room temperature. As with other vegetables thorough blanching is absolutely essential. All of the leading varieties appear to be about equally suitable for freezing storage as the principal varieties vary but little in flavor and texture.

Unfortunately asparagus collapses rather badly on freezing and thawing, hence is not very attractive in appearance after thawing. However, if quick-frozen, it is after cooking not markedly different in appearance from cooked fresh asparagus. It has a fresh asparagus flavor and color.

Green Beans (String or Snap Beans).—Green beans for freezing must be tender and relatively free of woody pod tissue and strings, as woodiness is made more noticeable by freezing storage. Moon, Caldwell, Lutz, and Culpepper found the Kentucky Wonder, Giant Stringless Green Pod, and Mosaic Resistant Stringless Green Refugee very satisfactory for freezing storage and decidedly superior to nine other varieties tested. Diehl reports Blue Lake and Wax beans also satisfactory.

Use beans promptly after picking. Cut off ends and remove strings if of a string-bearing variety. Asparagus style, or uncut whole pods are preferable to pods cut in short pieces. Blanch in live steam or boiling water 2 to 4 min., depending on the size and maturity of the pods. Cool thoroughly in cold water. Freeze rapidly at −30 to −40°F. Pack in either airtight or nonairtight containers. Store if possible at 0°F., as Moon and associates found rather serious deterioration in color at 15°F. Green beans are usually somewhat superior in appearance and flavor

if packed in cartons and cans and quick-frozen in the containers rather than in the loose condition on trays.

Lima Beans.—Frozen-pack Lima beans have proved very popular and promise to become important commercially. Caldwell, Lutz, and Moon have compared 8 common varieties for freezing storage and found King of the Garden, Giant Podded, both being pole varieties, and the Dreer Bush variety superior to the other varieties tested.

The Henderson Bush, a widely grown and popular garden variety, was satisfactory only when brine flotation was used to remove overmature beans. In fact, a prime requirement of Lima beans for frozen pack is that they must be of a variety that ripens *uniformly*, or segregation by brine flotation must be resorted to, as beans that are too mature are unattractive in color and flavor when preserved by freezing. There are hundreds of varieties of Lima beans, and among them there are probably several that are equal to or superior to those recommended by Moon and associates.

Pick the pods while the beans are still green. In large commercial-scale practice probably the entire vines would be harvested and the beans shelled direct from the pods on the vines by machinery similar to that used for shelling peas for canning. In this case quality grading by brine flotation would undoubtedly be necessary. Size grading in the usual manner as for canning is desirable but not so essential as for that purpose. Smart and Brunstetter found full-size green beans preferable to the small, partly developed, immature beans.

Blanch for 3 min. in boiling water, and chill thoroughly in cold water. Pack without brine; preferably in airtight containers. Freeze rapidly and store at 0°F. Caldwell and associates advise strongly against higher storage temperatures. Like peas, cut beans, and cut corn, Lima beans may be frozen in shallow trays or pans before packing. When so prepared, they are "free running" and any desired quantity while frozen may be poured readily from the container. The beans are also satisfactory when packed and frozen in 2 per cent salt solution.

Broccoli.—This vegetable has increased greatly in popularity in recent years. It responds well in frozen pack. Select a product of dark-green color, tender in texture, and as free as possible from stringiness. Sort and trim carefully to remove woody portions. Blanch 3 to 5 min., and cool thoroughly in cold water. If to be dry packed, place in containers that may be sealed, packing tightly. If packed in 2 per cent salt solution, nonairtight containers may be used. Freeze rapidly at a very low temperature and store at not above 15°F., preferably at 0°F.

Cauliflower.—While this vegetable may be preserved by freezing storage, it is usually available in the fresh condition throughout the year, and therefore there appears to be no great need for freezing it. Use fresh,

crisp, compact heads. Trim and cut into individual "curds" to facilitate blanching and packing. Blanch until well heated through, about 3½ min. in vigorously boiling water. Cool thoroughly in cold water. Freeze rapidly. Pack in tight containers without brine, or pack fresh in either airtight or other containers in 2 per cent salt solution and freeze quickly. Store at 0°F.

Corn.—Sweet corn has proved one of the most popular of frozen-pack vegetables. It is packed either as corn on the cob or as cut corn. The former style is preferred.

For use in frozen pack the varieties used should possess an extended period of succulence, tender texture, pleasing flavor, and if for packing as corn on the cob, a small well-filled ear with even rows of kernels. A yellow or golden color is at present preferred to the white. Consequently the Golden Bantam and some of its crosses have been most popular for freezing storage. Caldwell, Lutz, Culpepper, and Moon compared 35 varieties of corn grown for two seasons on the experimental plots of the U. S. Department of Agriculture near Washington, D. C. They placed the following yellow varieties in the first group in respect to desirability for frozen pack: Bantam Evergreen (Golden Evergreen), Bantam Evergreen hydrid (Asgrow 24 × Purdue 39), Golden Bantam, Golden Bantam 10 to 14 rowed, Top Cross Bantam, and Top Cross Whipple's Yellow; and the following four white varieties, Money Maker, Narrow Grain Evergreen, Stowell Evergreen, and Stowell Evergreen hybrid (Asgrow 14 × Asgrow 5). Of these, all except Stowell Evergreen, Stowell Evergreen hybrid and the Golden Bantam Improved 10 to 40 rowed were satisfactory for either corn on the cob or cut corn; these three varieties possess too large ears for packing as corn on the cob. Country Gentlemen, a well-known and very popular variety in the fresh market, and 12 other varieties were placed in the second group and rated nearly equal to those in the first group. Hence, there are many varieties suitable for frozen pack.

Diehl as well as Caldwell and associates emphasize that corn for frozen pack must be picked while tender, well before the "dough stage" and while still definitely in the milk stage. In the Washington, D. C., district this is at not more than 20 days after appearance of the silk.

Remove husks. Blanch until well heated through; if to be packed on the cob, blanch in boiling water at least 6 min. or in steam at least 8 min.; 3 to 4 min. is sufficient if to be cut from the cob after blanching. Corn on the cob may be packed in airtight or nonairtight containers and with or without brine. The trade at present prefers the brineless pack. Airtight containers retain the texture and flavor better than the nonairtight although the latter are used successfully. If brine is used, one containing about 2 per cent salt and 5 to 6 per cent sugar is recommended.

Corn cut from the cob is prepared either as whole-kernel style without scraping the cob, or as cream style by scraping the cob after cutting off the kernels at a considerable distance from the cob. The corn is blanched on the cob before cutting for both styles. The whole-kernel style is more attractive in appearance, although Caldwell reports the cream style richer and more pleasing in flavor. Either airtight or nonairtight containers may be used, although if the latter are used, it is recommended that a brine containing 2 per cent salt and about 5 to 6 per cent of sugar be added. For long periods of storage use airtight containers.

Freeze quickly at low temperature and store at 0°F. if possible. Caldwell found that cut corn stored in brine in paraffined cups at 15°F. for 6 months became very poor in flavor and that stored without brine in these containers was inedible. He recommends storage at 0°F.

Corn on the cob insufficiently blanched develops a pronounced cob flavor during storage; hence Caldwell recommends 7 min. blanching for this product. On the other hand Diehl recommends 3 to 4 min. There appear to be several other points requiring further study in connection with frozen-pack corn.

Peas.—At present peas are the most important of the frozen-pack vegetables. Peas for this purpose should be tender, sweet, of tender skin, and of deep-green color. Moon, Caldwell, and Lutz compared for frozen pack during two seasons 18 varieties of peas grown near Washington, D. C. The Thomas Laxton and Asgrow 40 were superior to all the others. Nearly as satisfactory were the Dark Podded Telephone, Onward, Alderman, and Laxton Superb varieties. Green Admiral, American Wonder, Market Surprise, Improved Stratagem, Improved Pilot, and Nott Excelsior possess defects, the most common being lack of color; however, they are of fair to mediocre quality for freezing storage. Alaska, Champion of England, Dwarf Telephone, Laxtonian, Pedigree Extra Early, and Wisconsin Early Sweet were found so inferior for frozen pack that they are definitely advised against by Moon and associates. Diehl states that if Laxton's Progress, Stratagem, and Alderman are planted, fairly continuous production through the season can be secured. It is customary also to space the times of planting of single varieties so that green peas will be available over a period of several weeks. Locality will determine the variety to be planted to a considerable extent.

If hand picking of the pods is followed, pickings should be frequent in order to secure the maximum amount of peas of prime condition. In large-scale operations for production of frozen-pack peas of low cost for competition with canned peas, undoubtedly the procedure used by canners would be followed, *viz.*, of harvesting the vines when most of the crop is at optimum maturity, threshing ("vining") the peas from the pods by standard pea machinery, cleaning by machinery, segregation into quality

grades by brine flotation (if necessary), size grading, and automatic blanching as for canning.

Diehl recommends 1 to 1½ min. blanching on a screen belt in flowing steam; Joslyn, Marsh, and Arighi recommend 2 min. in water at 185 to 190°F. In either method blanching must be sufficient to destroy enzymes. The blanched peas are chilled at once in cold water. Tressler and associates found that blanching in water removed a great deal of vitamin C, whereas but little was lost during blanching in steam.

Present markets prefer peas packed without brine. If packed in this manner, they may first be frozen in shallow layers at 0°F to about −40°F. The frozen peas may then be packed in airtight sealed cans, in paraffined paper cups, or in cartons lined with waxed paper or parchment paper. Moon and associates, as well as Diehl, recommend that a storage temperature of not above 0°F. be used, as undesirable color and flavor changes are apt to occur at higher temperatures, particularly in containers that are not airtight.

Peas packed in dilute brine retain their color and flavor more satisfactorily than when packed dry. For this reason it might prove a satisfactory method for the retail trade. Large users, however, prefer the dry pack for reasons previously given.

Tomatoes.—To date attempts to preserve tomatoes in frozen pack have been unsuccessful since they soften very badly on thawing and are then similar to canned tomatoes in texture. If the fruit could be maintained in firm condition suitable for use in salads, there would undoubtedly be a greater market for it.

Cooking Frozen-pack Foods.—Owing to the fact that freezing softens the texture of vegetables and fruits, frozen-pack products require much less cooking than the corresponding fresh products. Frozen-pack fruits are often served without cooking; either in the frozen condition or soon after thawing. However, large quantities of frozen-pack berries and lesser quantities of frozen apricots, peaches, and apples are used in making pies, preserves, jams, jellies, and other cooked products. Frozen-pack barreled strawberries are very suitable for use in preserves and ice cream, and preservers and ice-cream factories are the principal purchasers. The suitability of berries for jelly making is not materially altered by freezing storage, according to Joslyn and Marsh (*Bull.* 551), as the pectin content is only slightly diminished. The frozen fruits are treated similarly to the fresh in utilizing them for preserves, jellies, and jams.

Vegetables frozen in brine are thawed and cooked in the original brine, either after allowing to thaw at room temperature or after heating carefully over a low flame. Those packed without brine are placed into boiling water, seasoned to suit, and cooked a short time. Overcooking is the principal danger, as it gives a soft, mushy, or soggy product of poor

flavor and color. Cook only long enough to render the product of desirable texture and flavor; for peas, for example, this will usually be not more than 5 min. at the boiling point. When they are properly cooked, frozen peas, corn cut on the cob, string beans, Lima beans, and spinach are practically identical with the cooked fresh products.

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CHAPTER XXXII

VITAMINS

HISTORICAL NOTE

It has been known for several hundred years that fresh fruits and fresh vegetables will cure, as well as prevent, scurvy, formerly a common disease in armies and among sailors. It is recorded that about 1804 the British navy made a ration of lemon or lime juice compulsory as a scurvy preventative; hence the name "lime juicers" at one time applied to English sailing vessels.

Cod liver oil has long been known as a cure and preventive of rickets, general malnutrition, and certain eye affections; although it is only in recent years that the properties of the substances concerned have been established.

The first definite scientific knowledge of the vitamins began with the experiments of Eijkman about 1887 on the cause, cure, and prevention in the Dutch East Indies of beriberi, a serious and widespread deficiency disease of the Orient. Lunin, Pekelharing, Hopkins, and others between 1881 and 1906 also made observations that the diet must contain certain substances other than proteins, fats, carbohydrates, and mineral salts. Hopkins in England in 1906 reported that 3 cc. of milk daily in an otherwise artificial ration allowed laboratory animals to develop normally. He called attention to his belief that scurvy and rickets were deficiency diseases caused by lack of certain factors in the diet.

In 1911 Funk prepared from yeast crystals that cured polyneuritis. He gave the name of "vitamine" ("life amine") to the substance, thinking it an amine. It proved not to be an amine; nevertheless, the word coined by him became the name by which these essential, dietary accessories are known. Drummond in 1920 suggested that the anti-beriberi factor be called vitamin B; McCollum's fat-soluble factor vitamin A; and Holst and Frolich's antiscorbutic factor, vitamin C.

Space does not permit presentation of other historical notes on the vitamins. See Sherman and Smith "The Vitamins" for further information on the history of vitamin research.

DEFINITION AND GENERAL PROPERTIES

Vitamins may be considered as essential dietary accessories of fairly simple chemical composition, present in various natural foodstuffs in

varying concentration. They are characterized further by very great activity and the fact that continued absence of any one of them from the diet of suitable test animals results in a definite, diseased condition characteristic of the lack of the particular vitamin that has been omitted. They are less complex than proteins, and unlike enzymes, they are relatively heat stable, withstanding 100°C. in the absence of oxygen. They resemble hormones more than they do enzymes. They are, therefore, in the nature of powerful, biological catalysts. The chemical make-up differs according to the vitamin; these differences are discussed in the paragraphs devoted to the chemistry of the respective vitamins.

A normal, mixed diet usually provides an abundant supply of all the vitamins with the possible exception of D (the antirachitic, so-called "sunshine" or "cod-liver oil" vitamin). Therefore, proprietary vitamin concentrates and other vitamin preparations are usually unnecessary with a diet of the type mentioned. On the other hand there exist very large, undernourished populations subsisting on an inadequate diet such as one of polished rice or of corn bread and salt pork, who exhibit definite vitamin-deficiency diseases such as beriberi, pellagra, rickets, and scurvy. Now that the cause of these deficiency diseases is known, steps can be taken, insofar as economic conditions permit, to supply the lacking vitamins.

Canned foods are good sources of certain vitamins, as are also certain dried fruits and fruit juices. On that account canners and packers of foods should make themselves well acquainted with our present knowledge of the vitamins, particularly their behavior toward canning, drying, fermentation, and other processing operations.

DISTRIBUTION OF VITAMINS

Foods vary greatly in their vitamin content. For example, sucrose (cane or beet sugar), white flour, refined vegetable oils or refined vegetable fats, polished rice, cornstarch, most table syrups, and salt are either very poor in or devoid of vitamins, whereas fish-liver oils, compressed yeast, citrus juices, dried prunes, apricots, carrots, and spinach are each particularly rich in one or more vitamins. The following table summarizes their distribution. The symbols used in the chart have the following meanings:

± .... Low to very low concentration
\+ .... Fair to good concentration
++ .... High concentration
+++ .... Very high concentration
− .... Absent
? .... Doubtful, or data lacking

The information given in the table is based on a table prepared by Remington and published by the American Chemical Society and the

TABLE 81.—DISTRIBUTION OF VITAMINS C, B, G, AND A IN FRUITS AND VEGETABLES

	C	B	G	A
Fruits:				
Apple	+	+	++	+
Apricot	++	?	++	+++
Avocado	+	+++	++	++
Banana	++	+	++	+
Date, dry	−	++	+	+
Fig, dry	−	?	±	?
Grape	±	+	+	±
Grapefruit	+++	++	++	+
Lime	++	?	?	−
Lemon	+++	++	++	±
Mango	+++	++	++	++
Orange	+++	++	++	+
Peach	++	++	+	+ to ++
Pear	+	++	++	+
Pineapple	++	++	+	+
Prune, dry	−	++	+++	++
Raisin	−	++	+	−
Raspberry	+++	++	?	?
Strawberry	+++	++	?	+
Vegetables:				
Artichokes (globe)	?	+	?	++
Asparagus, green	+++	++	++	++
Asparagus, white	+++	?	?	−
Beans, string	+++	++	+	++
Beans, navy, dry	?	++	?	+
Beets, leaves	?	++	++	++
Beets, roots	+	+	±	+
Broccoli	+++	?	++	++
Cabbage, raw	+++	++	?	+
Cabbage, cooked	++	++	+	+
Carrots, cooked	+	++	+	+++
Cauliflower, raw	+++	++	+	+
Cauliflower, cooked	+++	+	+	+
Celery, bleached	?	++	?	±
Chayote	?	?	?	++
Cucumbers	++	+	?	++
Eggplant	?	+	?	+
Endive	+	?	?	+
Lentils	−	++	?	+
Lettuce, head	+++	++	+	+
Mushroom, dry	−	++	?	−
Okra	?	++	?	?
Onions, raw	++	+	?	±
Parsnips	?	++	?	±
Peas, green cooked	++	++	++	++
Peas, green canned	+	++	++	++
Peas, dry	?	++	++	+
Peppers, green	+++	++	?	++
Potatoes, cooked	+	++	±	+
Pumpkin and squash	+	+	?	++
Rhubarb	+	?	?	?
Sauerkraut	++	+	?	?
Soybeans	−	++	?	+
Spinach, canned	++	++	++	+++
Sweet potato	++	++	±	++
Tomatoes	++	++	++	++
Turnips, white	++	++	±	±
Turnips, tops	+++	+	+++	+++

South Carolina Food Research Commission in 1934 (revised 1938), a similar table published by the H. J. Heinz Co. in 1934 (now in 10th revision), Misc. Pub. 275 of the U. S. Department of Agriculture by Daniels and Munsell, 1937, and various original papers by Tressler and associates, Morgan and associates, E. F. Kohman, Kohman and Eddy, and others. Some of the information is provisional and subject to revision as additional research throws more light on the vitamins. In this table vitamin G is taken as the antipellagric vitamin, not merely lactoflavine. Perhaps PP, pellagra preventive, is a better term.

VITAMIN C

This vitamin is abundant in certain fruits and vegetables and since it is of great importance in human nutrition its retention in fruit and vegetable products is of concern to canners and others engaged in the processing and preservation of fruits and vegetables.

Place of Vitamin C in Nutrition.—At one time scurvy caused by lack of Vitamin C was a common disease in northern European countries, but with the introduction and adoption of the potato as a common article of diet scurvy as a definite, easily recognized affliction has nearly disappeared. Nevertheless, even if the symptoms of acute scurvy are not present, it is possible for the body to be seriously undernourished because of lack of sufficient vitamin C. Children in particular may suffer from vitamin C deficiency without exhibiting active symptoms of scurvy. The person affected is apt to be lacking in stamina and to suffer "rheumatic" pains in the joints and limbs. Tooth formation is apt to be defective and decay excessive, even when other symptoms are not apparent. Lack of vitamin C often causes weakening of the capillary walls. Small cutaneous hemorrhages are then apparent when a tourniquet is applied to the arm or when suction is applied to a small area of skin.

Administration of vitamin C by feeding orange juice, tomato juice, or other food rich in C causes such symptoms as the foregoing to disappear.

The guinea pig is the usual test animal in vitamin C experiments, as it will develop easily recognized symptoms of scurvy in about 2 weeks on a diet containing no or very little C. The animal's joints become tender and inflamed, the teeth in the growing animal are defective and abnormal in structure, and growth is slow or arrested. The teeth become loose, the bones brittle, and the rib junctions are enlarged. Hemorrhages occur on very slight injury and in advanced stages occur of their own accord at many locations in the animal.

Vitamin C Content of Foods.—By reference to the table given earlier in this chapter it can be seen that citrus fruits and their juices, and some vegetables are rich in C. The potato contains only a moderate amount

of C, but since it is eaten in large quantities by northern Europeans and by many Americans, it is an important source of the vitamin. Most fresh and canned fruits contain considerable C.

In the use of canned tomato juice it is well to ascertain that it is a brand proved to be rich in C; because careless preparation of this juice for canning results in loss of most of the vitamin. Morgan, Kohman and Eddy, also Tressler and associates have studied the vitamin C content of many fruits and vegetables. Citrus fruits are rich in C.

Stability of Vitamin C.—Vitamin C is very sensitive to oxidation and to heat plus oxidation, but it is reasonably stable to heat in the absence of oxygen. In some fruits and vegetables there is present a vitamin C oxidase or oxidase-like substance that very greatly accelerates destruction of C by oxygen. Tomatoes and apples appear to have an abundance of such an accelerator, whereas in citrus fruits there appears either to be little of it or there is present an antioxidasic substance. Kertez and associates report ascorbic oxidase in cabbage, squash, pumpkin, peas, string beans, Lima beans, sweet corn, chard, carrots, parsnips, and spinach. They stress the necessity of destroying the enzyme by heat in vegetables to be preserved by freezing storage. Vitamin C disappears very rapidly from aerated fresh apple and tomato juices. However, if tomato juice, for example, is deaerated to remove oxygen and is then heated to destroy the oxidase, vitamin C of the juice is quite stable.

Raw cabbage is rich in C but cooking may destroy much of it. Sauerkraut, fermented cabbage, is high in vitamin C according to Tressler.

In the drying of fruits it has been demonstrated by Morgan, Nichols, and Field at this University that most of vitamin C is lost if the fruits are not treated with sulfur dioxide before drying, the loss undoubtedly being due to oxidation. On the other hand, vitamin C is well retained in fruits well-sulfured before drying (see references at end of chapter for details).

Goss found that concentration of orange juice to a syrup did not noticeably alter its C content. Others have found that, if milk is dried carefully to a powder, vitamin C is injured but little.

It is less stable to heat and oxidation at high pH value, *e.g.*, at pH 7–9, than at a moderately acid reaction, *e.g.*, pH 3.8 to 4.2.

Orange juice preserved by freezing retains C well if deaerated and flash pasteurized before storage. Benzoated, unpasteurized apple juice loses all its vitamin C, according to Fellers. He also found that orangeade made by adding water to sweetened orange juice also rapidly loses its vitamin C.

Determination of Vitamin C Content of Foods.—Two methods of determining the vitamin C content of foods are available. The first is by feeding tests, thus determining the minimum quantity to protect a

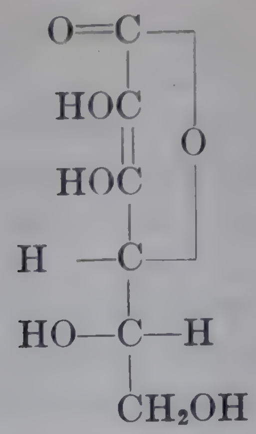
guinea pig against scurvy. The "Sherman unit" is that amount of vitamin C which fed daily will protect a guinea pig of standard weight (300 grams) against scurvy. Since vitamin C (ascorbic acid) has now been obtained in pure crystalline form the so-called "international vitamin C unit" also has come into being; it is 0.05 mg. of ascorbic acid (vitamin C).

The second method of determining vitamin C is by titration. Liquid foods or extracts of solid foods are titrated with standard 2, 6-dichlorophenol indophenol solution, the dye being reduced to the colorless leuco base by vitamin C; or the titration is made with standard iodine solution. The analyst must make certain that other reducing substances do not interfere with the titration. Titration does not determine the reversibly oxidized vitamin C that may be present, although this form of C may still be potent physiologically. It can be determined, however, by first reducing the solution with hydrogen sulfide. The titration method, nevertheless, is of great value if proper precautions and due allowances are taken (for details see papers by Bessey and King and by McHenry and Graham).

Chemistry of Vitamin C.—Zilva in England and others had for many years studied the chemical behavior of vitamin C in concentrates and in the natural food products, but they had not isolated it in crystalline form. Zilva, however, had prepared from lemon juice a very potent concentrate. Szent-Györgyi (1933) in Europe, in studies on oxidation and reduction phenomena in plant and animal tissues, isolated in crystalline form a very active hexuronic acid from the adrenal cortex (of the kidney) and from cabbage. He believed it of great importance in oxidation and reduction; but Zilva showed that the vitamin C content of lemon juice was apparently independent of Szent-Gyorgyi's "reducing factor" (hexuronic acid), consequently the latter dropped his study of it in relation to vitamin C.

In 1932 apparently he returned to a study of the antiscorbutic activity of his hexuronic acid and, as a consequence, reported (in *Nature*, **129,** 690, 1932) that it possessed great "vitamin C" potency. Almost simultaneously King and Waugh, at the University of Pittsburgh, reported isolation of a crystalline hexuronic acid from lemon juice and their finding that it is vitamin C. The discoveries of the two laboratories have been confirmed repeatedly by other investigators, and there is now no doubt that Szent-Györgyi's hexuronic acid is vitamin C.

Hawarth, Reichstein, and others, also Cox, Hirst, Reynolds, and others have now established the constitution of vitamin C, and it has been synthesized from xylose, galactose (through lyxose), and sorbose (the last being derived from glucose). The empirical formula is $C_6H_8O_6$, and the structural formula according to Reichstein and others is



This hexuronic acid is now known very generally as ascorbic acid. It has one double bond between the second and third carbon atoms which would account for part of its chemical activity. It contains one less molecule of water than one might expect for a normal hexuronic acid. Carbon atoms 4 and 5 are asymmetric; consequently ascorbic acid is optically active. Its crystals from different sources, natural and synthetic, have the same vitamin C potency.

Under certain conditions it may be oxidized reversibly, although strong oxidizing agents oxidize it irreversibly and thus permanently destroy its vitamin C potency. The reversibly oxidized form exerts antiscorbutic action in the animal body.

Vitamin C is l-araboscorbic acid; d-araboscorbic acid, identical with the l-form in all respects except in configuration of the fifth carbon atom, shows no, or at most very little, vitamin C activity. None of the other hexuronic acids possess antiscorbutic properties.

VITAMIN B (B_1)

Place in the Diet.—As stated in the historical note on the vitamins, vitamin B is the water-soluble, antineuritic, or antiberiberi vitamin. It prevents beriberi, a peripheral neuritis of the feet and legs of persons on a diet seriously deficient in this vitamin, and also prevents polyneuritis in fowls. On diets deficient in B young test animals lack appetite and fail to grow. Fowls become paralyzed in the wings and legs.

As stated previously vitamin B (B_1) was the first vitamin to receive systematic study. It was proved by Eijkman, working in the Dutch East Indies in the 1890's, that the natives on a diet consisting chiefly of polished rice developed beriberi. He also noted that chickens fed on leftover, cooked, polished rice from the table of the prisoners developed weakness and stiffness of the legs, similar to the condition of beriberi in man. This was probably the first recorded observation of a vitamin-deficiency disease of animals. He proved also that the antiberiberi factor resided in the bran of the rice.

Takaki of the Japanese navy and later, about 1900, American officers in the Philippines came to conclusions similar to those of Eijkman. They

were able to eradicate the disease by replacing some of the polished rice of the diet with barley, vegetables, or beans.

"Tikitiki," an extract made by dissolving the vitamin from rice bran and concentrating to small volume, is a vitamin B concentrate commonly used in the Philippines and elsewhere to provide the vitamin. It would appear much more logical to use unpolished rice, which is rich in B, rather than to use polished rice plus tikitiki.

Prolonged lack of vitamin B results in death of test animals or of human beings.

Distribution.—A mixed diet containing an abundance of vegetables usually provides an adequate amount of vitamin B. Cereal products made from the whole grain are valuable vitamin B foods. Wheat germs, now available at low cost, are very rich in B. A. F. Morgan of the University of California recommends them for children particularly. Yeast is also commonly used as a source of this vitamin for adults, in addition to its value as a mild laxative. Raisins contain considerable vitamin B, as do canned vegetables. In fact most fruits and vegetables contain important amounts of it.

As with vitamin C there is a subclinical level of vitamin B supply in the diet at which growth, appetite, and general well-being are subnormal without evidence of acute symptoms. It is probable that this condition is far more prevalent than the acute stages of beriberi. There is evidence also that vitamin B is in some manner, at present not clearly understood, involved in the metabolism of carbohydrates.

Stability and Composition of B.—Vitamin B is much less sensitive than vitamin C to oxidative changes. At temperatures used in processing canned nonacid foods, such as most vegetables and milk (240 to 250°F.), considerable loss in vitamin B occurs; particularly at 250°F. It is possible by autoclaving yeast at 250°F. to destroy practically all of B, leaving vitamin G uninjured. In other food products, also, G is much more resistant than B to heat. While some B is lost in retorting nonacid canned vegetables, nevertheless the canned green vegetables are still good sources of this vitamin. The B content of fruit juices preserved by pasteurization is practically equal to that of the fresh.

Morgan, Nichols and associates have found that B in fruits and fruit products is destroyed by moderate to high concentrations of sulfur dioxide (120 to 3,000 p.p.m.) such as used in treating cut fruits before drying. This finding agrees with the discovery by Williams that the vitamin is split quantitatively by sulfite. While sulfur dioxide destroys B in fruits treated heavily with sulfur dioxide for drying, it protects A and C in these same fruits. Prunes, raisins, dates, and most figs are dried without use of sulfur dioxide, hence their B content is relatively undiminished by drying. Much of the B content of grapes is lost when the juice is

converted into wine owing to destruction by the SO_2 commonly used in wine making.

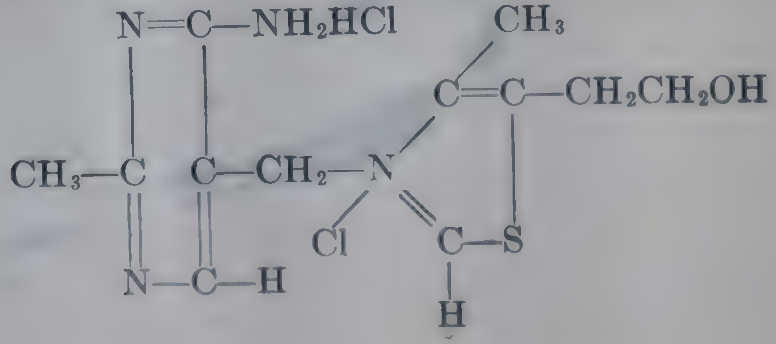
In juices and fruits preserved by freezing storage, it has been demonstrated by A. F. Morgan and associates that B is rather rapidly destroyed, probably by an enzyme, since there is less decrease in the heat-pasteurized juices.

Destruction of B is much less important than its removal from some cereal products in milling operations. In the dehydration of vegetables vitamin B is quite well retained according to recent data of MacKinney and Sugihara of this laboratory (1942, in press).

Chemistry of Vitamin B.—Vitamin B is water soluble and often is associated with Vitamin G. At one time B and G were considered a single vitamin, termed B. It is now known that there are several vitamins in the B complex and possibly more than one in what is now known as the G or B_2 complex.

As previously stated Funk in 1911–1912 obtained from yeast a crystalline substance containing nitrogen. It was given the formula $C_{17}H_{20}O_7N_2$. His formula was proved incorrect, and it was not until recently that the composition and configuration of B were solved. Jansen and Donath prepared a crystalline substance of high vitamin B potency from rice polishings and believed it to be $C_6H_{10}ON_2$. Ohdake in Japan in 1931 announced the isolation of 1.31 grams of "oryzanin" crystals from 6,000 kg. of rice polishings. It was of high B potency. He gave it the formula $C_{12}H_{16}O_2N_4S$. Windaus and associates in 1931, by adsorption of the vitamin of fuller's earth, fractional precipitation with silver and mercuric salts and benzoylation, prepared a concentrate from which on dilution they prepared a crystalline gold salt. From it they prepared the crystalline vitamin. The vitamin was proved to contain sulfur as well as nitrogen. The formula was $C_{12}H_{17}N_3OS$.

Williams and associates studied crystalline vitamin B, finding that sulfite at pH 5.0 splits it into a water-soluble base and an acid. The base was later (1935) synthesized by Clark and Gurin and found to be 4-methyl-5-β-hydroxyethylthiazole. In 1936 Williams and Cline synthesized vitamin B, definitely establishing the formula given by Williams. The chloride is of the following constitution:



Determination of B Content of Foods.—Now that vitamin B is purchasable in crystalline form the investigator can accurately compare foods of unknown B content with standard preparations of the crystalline vitamin. Feeding methods with rats (gain in weight) are still used as a common means of comparison, although the development of practicable chemical methods of assaying foods for B content are now available, one being the thiochrome method.

The quantity of B that will suffice to support an increase in weight of a test rat of 3 grams per week is considered one Chase and Sherman unit. This unit can also be expressed in terms of the crystalline vitamin.

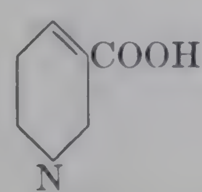
Pigeons are also rather generally used as subjects for determination of the daily quantity of a given food required to prevent polyneuritis.

NICOTINIC ACID, OR PP VITAMIN

This vitamin is usually associated with vitamin B (B_1) in such foods and food products as yeast, green vegetables, fresh lean meat, eggs and liver; and is the so-called antipellagric vitamin. The nomenclature of this and other vitamins of the B complex is undergoing change.

Place of Nicotinic Acid in the Diet.—A deficiency in the diet of rats used as test animals is accompanied by cessation of growth and loss in weight. Later soreness of the eyes and mouth occasionally develops. The paws often become red and inflamed. Loss of hair may also occur, particularly from the ears, paws, chest, and legs. The rats become weak and lethargic, whereas on a B_1 deficient diet they eventually become nervous and irritable. The spleen and thymus undergo atrophy, and hemorrhages develop in the intestines. These symptoms are cured by feeding nicotinic acid concentrates or foods rich in nicotinic acid.

It was found by Goldberger and others that certain foods such as vegetable greens, yeast, fresh lean meat, milk, liver, and eggs counteract pellagra in human beings. This is a disease prevalent among people who subsist on a diet consisting principally of corn bread or other foods made with corn meal, or a restricted diet such as corn bread and salt pork. It is encountered in the Southern States of the United States, Northern Italy, Rumania, and southern Russia in sections where corn is the principal component of the diet. Black tongue of dogs on a deficient diet is cured by administering nicotinic acid. The formula of nicotinic acid is



It is very stable to heat, oxidation and drying.

At present it is not clear to what extent a single vitamin, is concerned in pellagra prevention and to what extent other factors are involved. Sherman states that pellagra, in the usual broad significance of the term, is not caused by a simple vitamin deficiency. It is possible that two or more vitamins and a protein, or at least certain amino acids, are concerned in pellagra as broadly conceived. It has been suggested also that pellagra may be favored by a toxic substance formed during partial spoilage of maize by microorganisms. The adult human daily requirement is set at about 20 milligrams.

Vitamin G Content of Foods.—Recently the work of Karrer, Booher, Kuhn, and others has resulted in the isolation from milk, egg white, liver, and other sources of a crystalline flavin termed commonly vitamin G. It is likely that this flavin is not the factor concerned in pellagra; but on the other hand, it may be of importance in the pellagra "picture." Sherman states that the term "vitamin G" as used in the literature on normal nutrition and food values may now be considered as standing for the flavin factor, although not necessarily the antipellagric factor. In this book the writer is taking vitamin G to mean riboflavin. So many papers are appearing at present on various fractions of the vitamin G and B complexes, and terminology varies so greatly, that the nomenclature of the members of this group is badly confused.

It is customary at present to consider the riboflavin value of foods equivalent to their G content. One unit of G is that quantity fed daily to a standard test animal under conditions specified in the "Vitamin Monograph" of the American Chemical Society, which will cause an increase in weight of 3 grams per week during the test period. However, a more common and more useful unit of measurement is milligrams per 100 grams; or gamma per gram. A gamma in this case is .001 milligrams or .000001 grams. One rat unit mentioned above is now known to be about 2 to 3 gamma, that is, 2 to 3 micrograms.

Liver is a rich source of G, possessing 800 to 1,200 units per 100 grams; kidney, about 800; egg white, 60 to 120; egg yolk, 150 to 300; milk, 34 to 100; apricot, fresh, 42; broccoli, average, 40; kale, 140 to 220; Lima beans, fresh, 100; cauliflower, 60 to 87; corn meal, 33; dried figs, 33 to 50; mangoes, 90 to 105; mustard greens, 150; oranges, 15 to 65; pears, 22 to 100; potatoes, 15 to 31; prunes, dry, 266 or more; peas, fresh, 100; spinach, 100 to 174; tomato, 12 to 28; turnips, 17 to 50; turnip greens, 300; and dried yeast 750 to 1,600. Of particular interest to canners and dried fruit producers is the high G content of Lima beans, beet greens, turnip greens, spinach, dried prunes, mangoes, and peas.

Stability of Vitamin G.—This vitamin is very stable toward heat, drying, and oxidation. Temperatures used in the cooking, processing, and preservation of foods do not materially affect it. In this respect it differs

from B (B_1), and as previously stated, if yeast is autoclaved for several hours at about 250°F., most of B is destroyed and G is relatively unaffected. While sulfur dioxide used in drying fruits destroys B, it appears to have no effect on G.

It is, however, water soluble. Hence if vegetables are heavily blanched in boiling water for canning, freezing, or drying much of G as well as C and B may be lost.

Chemistry of Vitamin G.—For a number of years little was known of the chemical nature of vitamin G. Recently, however, Kuhn, Karrer, Booher, and others have isolated from milk and other natural substances a water-soluble greenish-yellow crystallizable substance which possesses certain of the properties attributed to vitamin G; they have christened it lactoflavin.

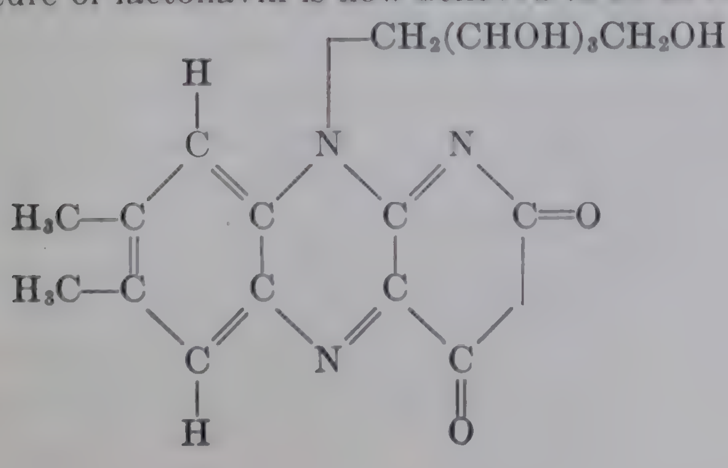
It is growth promoting when added to the diet of rats; a dose of 3 gamma (0.003 mg.) causes an increase in weight of about 0.9 gram daily in a standard test rat. It appears to be also an anticataract factor for rats but not the antipellagric factor. Its place in human cataract prevention is not definitely known; but at present many vitamin specialists believe it is not materially involved.

The yellow enzyme of Warburg, Theorell, Kuhn, and others is closely related to riboflavin, nevertheless. It is believed that this yellow enzyme, which is a hydrogen carrier (dehydrogenase), is in its natural state in living tissue a compound of flavin, phosphate, and a protein. This is the first case of proved relationship between an enzyme and a vitamin.

The flavin of foods can be isolated in partially purified form in solution and its concentration measured spectrophotometrically; although further research is necessary before quantitative correlation between the results of animal feeding tests and spectrophotometric data can be made.

Flavins and their products act as reversible oxidation-reduction systems and may therefore be of importance in oxidative and reductive changes in animal and plant tissues.

The structure of lactoflavin is now believed to be as follows:



The sugar of the side chain in the formula is d-ribose; other five-carbon sugars might be substituted, giving similar flavins, which may or may not show vitamin activity.

Recently a substance has been synthesized by Kuhn and Weygund having the properties of riboflavin.

Lepkovsky of this University is studying the vitamin G complex and has given considerable prominence to his "filtrate factor" of this complex. One component of the filtrate factor concentrate cured chick "pellagra." It is now known to be pantothenic acid.

VITAMIN B_6, PYRIDOXIN

There is evidence that there is present some foods a heat-stable water-soluble vitamin, the absence of which from the diet results in a form of dermatitis in rats, somewhat different from that caused by lack of riboflavin. It is described as a florid type of dermatitis, whereas that due to lack of G is a nonspecific form of dermatitis. Growth ceases when this vitamin B_6 (also called Pyridoxin) is withheld. Egg white is rich in G but very poor in Pyridoxin; Szent-György reports the muscle of herring, salmon, and haddock to be rich in B_6 and low in G.

It is not clear whether B_6 is concerned in human pellagra. The vitamin is being investigated intensively, and its properties are now quite definitely established. Its lack in the diet of rats results in rat pellagra. Its empirical formula is $C_8H_{11}NO_3$ and is 2-methyl-3-hydroxy-4, 5 di(hydroxymethyl)-pyridine. It is stable to heat.

VITAMIN A

Vitamin A is the fat-soluble, antixerophthalmic vitamin, also sometimes known as the "antiinfective" vitamin.

Place of Vitamin A in the Diet.—Lack of vitamin A results in retarded growth in the young, an effect produced by many other dietary deficiencies. Night blindness is a more characteristic symptom of A deficiency. Persons and animals so affected do not see well at dusk or in going from a well-lighted room into dim light. Liver and liver oils have been used for many years as a cure for this condition in human beings; it is now know, of course, that vitamin A is the curative agent.

With continued lack of vitamin A, the eye may be so severely injured by keratinization and ulceration that sight is lost. The addition of cod-liver oil or other good source of vitamin A or the feeding of carotene rapidly cures xerophthalmia caused by previous A deficiency.

There is a difference of opinion as to the value of vitamin A as a preventive of infection, although some authorities believe that it possesses definite antiinfective properties. Among populations subsisting on a diet lacking or seriously deficient in cream, butterfat, and carotene-

containing vegetables, xerophthalmia is often prevalent. A mixed diet, which includes generous amounts of butter or whole milk and green vegetables, will furnish an adequate amount of vitamin A.

Vitamin A Content of Foods.—In order to compare the Vitamin A potency of various foods either the "old" ("Sherman," "A.C.S.," or "U.S.D.A.") unit or the "new" International unit may be used. The former is that amount which fed daily under standard, specified conditions just suffices to support a rate of gain in weight of 3 grams per week in a standard test animal. The International unit is equivalent to 0.60 gamma (0.0006 mg.) of pure β-carotene. According to the U. S. Pharmacopoeia one may convert the old units into the new or International units by multiplying the former by 1.4.

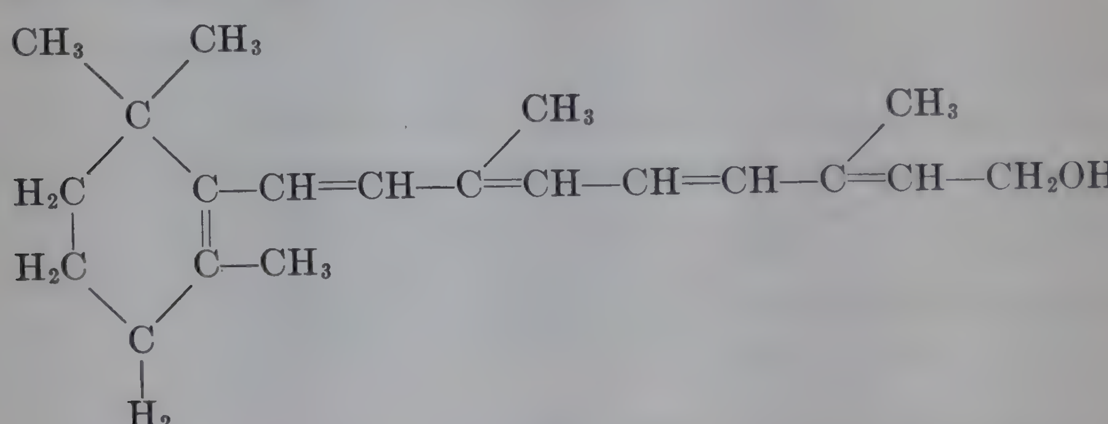
The vitamin A equivalents of several foods as expressed in International units per 100 grams are as follows: green asparagus, 350 to 1,500; string beans, 580 to 1,400, broccoli buds, 9,660 to 12,600; sprouts, 420; white cabbage, 14 to 140; cauliflower, 70; carrots, 4,500 ±; spinach, 20,000 ±; tomato purée (unconcentrated), 1,000 ±; turnips, 0 to 22; turnip greens, 7,400 to 9,900; apples, 100 ±; apricots, 4,480 to 12,040; cherries, 300 to 1,660; cranberries, 28; mangoes, 2,100 to 3,500; olives, 126 to 406; orange juice, 61; yellow peaches, 70 to 2,800; pears, 8 to 20; pineapple, 28 to 100; dried prunes, 900 to 3,460; and raisins, 0 to 178. Liver contains about 10,000, butter about 5,000, and cow's milk about 300 International units of A equivalent per 100 grams.

The A content of milk and of butter depends upon the carotene content of the cow's ration.

Stability of Vitamin A.—Vitamin A, or rather its precursor carotene, is quite resistant to the temperatures used in the processing of canned vegetables and fruits. It is however susceptible to oxidation; consequently, as shown by Morgan, Field, and Nichols, in the sun drying of cut fruits much of vitamin A is lost, unless oxidation is prevented by treating the fruit with sulfur dioxide before drying. In this respect it resembles vitamin C and differs from B_1; the latter is destroyed by sulfur dioxide. Aeration of cod-liver oil at 100°C., as previously stated, gradually destroys A but does not affect D. Vitamin A appears to be stable in the canning of milk and in the manufacture of dairy products such as butter and cheese.

Chemistry of Vitamin A.—The elucidation of the chemical nature of vitamin A and its precursors was based on investigations, (1) of the unsaponifiable fraction of fish-liver oils and (2) upon the carotenoid pigments of plants. Drummond and associates in England found that, by saponification of cod-liver oil with hot potassium hydroxide, vitamin A remains in the unsaponifiable fraction which can be recovered by fat solvents. The relative concentration of vitamin A in such concentrates

could be measured colorimetrically on addition of arsenic trichloride or antimony trichloride, which give brilliant colors with the vitamin. Also there is selective absorption of light by vitamin A in the ultraviolet at 3280 Å. Later it was found that halibut-liver oil is about 1,000 times as rich in A as is cod-liver oil. A considerable amount of unsaponifiable residue prepared from this oil was treated to remove sterols and other inactive material and was then fractionally distilled under a very high vacuum in a so-called molecular vacuum still. The vitamin distilled over with very little loss at 137 to 139°C. The distillate was a clear pale-yellow viscous oil. Karrer in Zurich also, at about the time of Drummond's work (1931–1932), obtained similar results. The most active component of his most highly potent fraction was an unsaturated alcohol, $C_{20}H_{30}O$. Heilbron in England in 1932 isolated vitamin A from halibut-liver oil and found it to have the empirical formula $C_{20}H_{30}O$ as did Karrer. He gives its provisional formula as



This formula is closely related to that of β-carotene; if the molecule of the latter were split in half, an atom of oxygen and two of hydrogen added (a molecule of water), one would get 2 molecules of vitamin A.

The history of research on the relation of carotene and other carotenoids to vitamin A will be summarized very briefly. It had been suspected that there was some relation between the yellow color of certain foods and their vitamin A potency. In 1919 Steenbock in America prepared crystalline carotene and fed it to test animals depleted of A. The response was not consistent or conclusive, because unknowingly, in depleting his animals of A, he also depleted them of D, as the two vitamins were not clearly defined at that time.

In 1928 Von Euler in Stockholm repeated Steenbock's experiments, but provided, in addition to crystalline carotene, vitamin D. His animals responded positively in very convincing manner. Others confirmed his results and definitely proved that the remarkable vitamin A potency of crystalline carotene is not due to an adhering impurity.

However, it was also well known that vitamin A is practically colorless, whereas carotene is orange red in color. Moore at Cambridge and

also Karrer, Kuhn, and others have solved this mystery by showing that in the animal body carotene is split and a molecule of water added with formation of vitamin A. Apparently animals cannot synthesize vitamin A but must secure it from carotene or one of its close relatives.

By reference to Chap. XXXIII it will be seen that β-carotene has two β-ionone ring structures, one at each end of the molecule. When split in half, two molecules of vitamin A can be formed from one of β-carotene. On the other hand α-carotene and γ-carotene have only one β-ionone ring and, therefore, can yield only one molecule of vitamin A. Lycopene, the red pigment of tomatoes, has no β-ionone structure, the ends of the molecule being open; hence it has no vitamin A potency.

There is evidence that the transformation of carotene into vitamin A in the animal body is not complete.

Determination of the A Content of Foods.—The animal-feeding technique is similar to that used in estimating the water-soluble vitamins. Rats are generally used as the test animals. Crystalline β-carotene may be fed in accurately graduated doses to some of the animals in order to provide a quantitative basis of comparison.

The carotene content of the food can be determined quantitatively by extraction with a fat solvent, separation from chlorophyll, and estimation in solution colorimetrically or by spectroscope.

As previously stated the International unit for vitamin A activity is that of 0.6 gamma of β-carotene (0.0006 mg.).

VITAMIN D

The value of cod-liver oil as a preventive and cure for rickets has long been known, although the discovery of the vitamin responsible for this activity and establishment of its chemical properties are relatively recent achievements. Vitamin D was the first vitamin to be isolated in pure form. While it does not occur in important concentrations in fruits and vegetables, nevertheless, since its precursor, ergosterol, is found in fixed oils of plant origin, it is desirable that attention be given it in this chapter.

Place of Vitamin D in the Diet.—When vitamin D is lacking in the diet of children and young animals, calcification of the growing bones does not occur normally. There is insufficient deposition of calcium and phosphorus to give to the bones their proper strength and rigidity. The bones of the legs often bend under the weight of the body and the child or animal is then bowlegged. The joints often enlarge in a characteristic manner, and the affected child may become knock-kneed. The formation of hard, sound teeth also requires an adequate amount of vitamin D in the diet. Vitamin C is also involved in the formation and continued sound condition of teeth. Rachitic children are apt to grow slowly.

Rickets may be very evident and easily recognized or may be subclinical in character. Surveys have shown that the disease is still

common. As the cause and prevention of the disease are becoming better known to parents throughout the world, rickets is rapidly being brought under control, either by including in the diet fish oils or irradiated foods high in D or by sun bathing and use of ultraviolet irradiation of the body.

Rickets may be caused not only by lack of D but also by insufficient calcium or by insufficient phosphorus.

In 1924 Steenbock and Black of Wisconsin University demonstrated that certain foods when irradiated with ultraviolet light acquired marked antirachitic properties. Hess independently discovered the same fact in 1924. Irradiated oils and other irradiated preparations rich in D are now on the market.

The feeding of excessive doses of vitamin D (*i.e.*, one form of D formed by irradiation) may induce deposition of calcium phosphate in other tissues than the bones with seriously harmful results. Some authorities on vitamins hold that a toxic substance is formed under excessive irradiation of ergosterol and that this substance is, in part at least, responsible for the adverse effects of excessive doses of irradiated D concentrates.

Vitamin D Content of Foods.—At one time it was thought that common foods were devoid of, or very poor in, vitamin D; because the antirachitic experimental diets were so drastic that rickets developed in the experimental animals in spite of appreciable amounts of D in some of the foods tested. By more appropriate diets it has been shown by Mellanby and others that egg yolk, butterfat, cheese, cream, green vegetables, and milk contain readily measurable amounts of D. Egg yolk has considerably more D than other common foods.

The D content of yeast, milk, and other foods containing ergosterol can be greatly increased by irradiation with ultraviolet light; that of milk can be increased also by irradiation of suitable ingredients of the cow's ration and by feeding vitamin D concentrates.

Formation of D by Irradiation of the Skin.—Apparently the skin contains a substance, probably ergosterol or a related sterol, that on irradiation of the skin with sunlight or ultraviolet light is converted into vitamin D, since it is well established that such treatment cures and prevents rickets. If the skin is washed with ether prior to irradiation, most of the antirachitic effect of ultraviolet is lost. Evidently the substance concerned is in the sebaceous secretion of the skin.

The wave lengths of sunlight responsible for D formation in the skin are screened out by ordinary window glass. Also clouds and fog remove most of this light. Winter sunlight is not very effective in forming vitamin D since it must pass through a great thickness of atmosphere. Bright summer sunlight, however, is a very effective antirachitic agent.

Chemistry of Vitamin D.—The finding by Steenbock and Black and independently by Hess that ultraviolet irradiation of certain foods gave

them antirachitic properties led to a search by many investigators for the responsible compound. It was found that this substance existed in the unsaponifiable fraction of the lipoids extracted from foods by fat solvents; also that it existed as an impurity in cholesterol separated by crystallization from the unsaponifiable lipoids. Later it was demonstrated that the activatable compound was ergosterol, already known as a constituent of ergot.

Rapidly, in several laboratories the pure "vitamin D" formed by irradiation of ergosterol was separated from the residual ergosterol and nonvitamin D products of irradiation. Fractional distillation of the irradiated ergosterol at very low pressure (0.0001 mm.) followed by fractional crystallization gave very potent crystalline products. Windaus and associates, Angus and associates, Reesnik and Van Wyk, and many others were engaged in studies of irradiated ergosterol. Angus and associates in England christened their product calciferol. Windaus at Göttingen called his synthetic vitamin, D_2. Both crystalline products possessed extremely high D potency. Very short ultraviolet waves are destructive to the vitamin.

The empirical formula for calciferol and Windaus's D_2 is the same as that of ergosterol. Conversion of the latter into D is apparently merely a transformation within the molecule. Prolonged irradiation converts D into products without antirachitic power. Both ergosterol and D formed by irradiation have one hydroxyl group but the number of double bonds is increased by irradiation.

There is now evidence that other compounds than ergosterol can be converted into antirachitic substances by irradiation. It has also been found that vitamin D formed by irradiation of ergosterol is a much less potent antirachitic for chicks than is the natural D of cod-liver oil, indicating that the two are not identical chemically. Irradiation of oils or fats of animal origin gives antirachitic substances resembling D of cod-liver oil, and irradiation of oils of plant origin give a substance identical with or similar to that obtained by irradiating ergosterol. There may, therefore, be several forms of vitamin D.

Determination of Vitamin D in Foods.—Since the principal function of vitamin D is to promote proper bone formation the methods used for determining the vitamin D potency of various foods consist in measuring in some manner their effect on bone development in young animals, usually rats or chicks (see Sherman and Smith, "The Vitamins," for details).

VITAMIN E

Vitamin E is a fat-soluble heat-stable vitamin occurring generally in green vegetables and the germ of cereals. Its existence was suggested by

Mattil and Conklin in 1920, when they observed that rats maintained on a whole milk diet were usually sterile. In 1922 Evans and Bishop at the University of California proved beyond a doubt that a rat-anti-sterility vitamin is present in cereal germ and cereal-germ oil.

Later it was found by Evans and associates that lettuce is rich in E and that it occurs abundantly in other leafy vegetables. Lard has the peculiar property of destroying E potency, a fact that caused much confusion in the early studies on this vitamin by Nelson and others, who were led to dispute Evans's work on this account. However, it is now generally recognized that vitamin E is a definite, specific entity.

Whether it is essential for other animals, including man, is still an unsettled question. Rats appear to be peculiarly susceptible to E deficient diets. Recently (1936) clinical observations indicate that it may be an important factor in preventing abortion in women who are normal in all other respects, *i.e.*, normal anatomically and free of abortion-causing diseases.

Recently Evans and associates have further concentrated vitamin E by forming an allophanate with cyanic acid and later removing the cyanate radical. Three milligrams was sufficient to allow successful pregnancy in the rat. They find it to be an alcohol and tentatively gave it the empirical formula $C_{20}H_{50}O_2$. The substance responsible for E potency exhibits a strong absorption band for ultraviolet light at 2940 Å. It has now been identified as α tocopherol, $C_{29}H_{50}O_2$.

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CHAPTER XXXIII

PLANT PIGMENTS AND RELATED COMPOUNDS

Fruit and vegetable pigments, tannins, flavones, and certain glucosides are of interest and importance to those engaged in the fruit products industries. For example, in the canning of green vegetables, retention of the fresh green color of the chlorophyll is only a partially solved problem and one meriting much more scientific study than has been accorded it. Carotene is the precursor of vitamin A in foods. The anthocyanin pigments give color to fruit juices, jellies, wine, and other products and are actively concerned in corrosion of cans. The tannins are involved in the browning of freshly cut fruits, in the ripening of dates and persimmons, in the darkening of frozen-pack fruits, and probably to some extent in the darkening of dried fruits. Also, they impart astringency to certain fruits and wines and are of importance in the fining of wines. The role of flavones and flavonols is not so clear. A typical glucoside is oleuropein, the bitter principle of the olive. In olive pickling it is destroyed by sodium hydroxide.

CHLOROPHYLL

Chlorophyll, from the standpoint of plant metabolism, is the most important pigment in the plant kingdom, for the reason that photosynthesis is dependent upon it. It applies the energy of sunlight to the fixation of carbon dioxide and conversion of carbon dioxide and water into compounds from which plant tissue is built.

Chloroplasts.—While to the unaided eye a green leaf appears to be filled with a continuous layer of chlorophyll, microscopical examination shows that this green pigment is not equally distributed throughout the cells, but is concentrated in minute structures, termed chloroplasts. They vary in size, but are most frequently about 0.005 mm. in diameter and range from about one-half to about twice this diameter. They vary even more greatly in shape. The number ranges from 1 to more than 40 per cell.

The chloroplast or plastid does not consist of solid chlorophyll, but appears to be a sponge-like structure in which the chlorophyll is enmeshed. The pigment is principally at the surface of the plastid so that it can absorb as much light as possible.

Doubtless the chloroplasts are separated from the remainder of the cell in some definite manner, as by a "membrane" or at least a "bound-

ary," and possess characteristic permeabilities. During photosynthesis, carbon dioxide is taken in by the leaves, and an approximately equal volume of oxygen is given off. At night when the sun's rays are no longer available, the leaves respire, *i.e.*, take in oxygen and give off carbon dioxide as do other higher organisms. This process also occurs simultaneously with photosynthesis in sunlight.

During photosynthesis, sugars and starch accumulate in the green tissues. During the night, starch tends to disappear through hydrolysis by enzymes and by translocation. That starch does not require sunlight for its formation is shown by the experiment that leaves will accumulate starch in the dark when floated on a dilute sugar solution. At any rate, carbohydrate synthesis and photosynthesis are closely related, even if chlorophyll itself may or may not conduct all steps in the process.

Of practical significance to canners and other users of green vegetables is the fact that respiration continues after removal of the vegetables from the vine or soil. Dry matter is lost as carbon dioxide and metabolic water; starch may be hydrolyzed to sugar; and other profound changes may occur. Lignification (formation of woody tissue) may take place, as in asparagus after cutting. Sugar may disappear, as it does in green peas on standing, owing probably to respiration or to conversion to starch.

The green color of the plastid is insoluble in the other cell contents and in water; hence it remains in its typical "granules" and does not appear in diffused solution in the cell. Thereby it differs from the sap-soluble pigments, *viz.*, the anthocyanins and flavones, and resembles the other plastid pigments, *viz.*, the carotenoids.

Chemistry of Chlorophyll.—The average chlorophyll content of fresh green leaves is between 0.1 and 0.2 per cent by weight.

Berzelius in 1839 attempted unsuccessfully to isolate chlorophyll from green leaves; and it remained for Willstätter and his students in the first decade of this century to devise a successful technique of isolation and purification and to establish its composition and constitution.

After examining chlorophyll from over 200 kinds of plants he concluded that there is only one chlorophyll and that it exists in two forms, *a* and *b*. Previous investigators had thought that there were many chlorophylls; one claimed to have isolated six kinds of chlorophyll from a single plant.

Willstätter showed that chlorophyll *a* has the formula $C_{55}H_{72}O_5N_4Mg$ and chlorophyll *b*, $C_{55}H_{70}O_6N_4Mg$. In most of the higher plants the ratio of *a* to *b* is about 31 to 11; in green algae about 31 to 22, and in brown algae about 16 to 1.

Both chlorophylls are amorphous and insoluble in water. It is probable that they exist chloroplastin in the cell and in that form make contact with the surrounding aqueous solutions of the cell. When

dissolved in alcohol, crystalline products can be secured on concentration, although alcoholysis occurs under such a condition and the phytyl group is split off, being replaced by a simple alcohol radical. These facts led some of the earlier investigators astray. The two chlorophylls differ in solubility in organic solvents. They are soluble in alcohol, acetone, chloroform, ethyl ether, pyridine, benzene, petroleum ether, and other fat solvents. Willstätter separated them by partition between petroleum ether and methyl alcohol; component *a* enters the petroleum ether and component *b* the methyl alcohol layer. Chlorophyll *a* in solution is blue-green in transmitted light and blood red by reflected light, while *b* is yellow-green by transmitted and brownish red by reflected light. Both exhibit fluorescence.

Both *a* and *b* appear to be esters of a complex aliphatic alcohol, known as phytol or phytyl alcohol, whose empirical formula is $C_{20}H_{40}O$. Phytol constitutes about 30 per cent of the chlorophyll molecule.

On hydrolysis of chlorophyll *a* with cold dilute potassium hydroxide, there are obtained equimolecular quantities of phytyl alcohol, methyl alcohol, and chlorophyllin, $C_{31}H_{30}N_4Mg(CO)(COOH)_2$.

On more severe alkaline hydrolysis several other "phyllins" are formed by progressive, stepwise removal of carbon dioxide.

On gentle treatment with acid, *viz.*, alcoholic oxalic acid, the phyllins are converted into porphyrins, which are compounds with four nitrogen atoms and four pyrrole rings each. If chlorophyll is first treated with acid to remove magnesium and is then treated severely with potassium hydroxide there is obtained phylloporphyrin, $C_{16}H_{18}N_2O_3$, which forms reddish crystals and is related to hematoporphyrin, a similar substance obtained by alkaline hydrolysis of hemoglobin. This and other established facts indicate a fairly close relationship between the two important pigments hemoglobin and chlorophyll, as well as a possible similar origin.

When chlorophyll is treated with acid, even very dilute acid, the color changes from green to olive-green or greenish brown. The hydrogen of the acid replaces magnesium in the chlorophyll molecule, and a series of products known as phytins are formed, their composition varying according to the extent of the decomposition; chlorophyll *a* gives on acid treatment phaeophytin *a*,

$$(C_{32}H_{32}ON_4)\left\langle\begin{matrix} COOCH_3 \\ COOC_{20}H_{39} \end{matrix}\right. .$$

Chlorophyll *b* yields a slightly different phaeophytin. When green leaves are removed from the plant and are allowed to stand, autolysis of the tissues with liberation of organic acids occurs, and these in turn cause decomposition of chlorophyll to phaeophytin. This change also

occurs during the canning of green vegetables such as spinach; the vegetable changing from green to gray or grayish green in color. In the pickling of green cucumbers, string beans, green olives, and other green foods, lactic acid is formed by fermentation or the products are placed in vinegar (dilute acetic acid); with the result that chlorophyll is decomposed to phaeophytin with a corresponding change in color from green to yellow, yellowish green, or grayish green.

If the vegetables are impregnated with a few parts per million of copper in the form of a copper salt such as copper sulfate, the green color is retained. At one time French canned peas were artificially colored in that manner; as little as 20 p.p.m. of copper is sufficient. This practice is forbidden in the United States.

Canning green vegetables in a slightly alkaline brine also retains much of the green color of the chlorophyll; but such high temperatures are then required for sterilization that the product is spoiled in texture and flavor.

However, it has been observed that blanching of spinach at about 160°F. instead of at the boiling point causes it to retain its color much more satisfactorily after canning. The cause for this easily demonstrated difference in behavior is unknown, although considerable experimental work has been conducted on the problem by the laboratories of two of California's large canning corporations. One plausible hypothesis is that blanching at 160°F. liberates, but does not destroy, chlorophyllase, an enzyme which converts chlorophyll to phyllin, and the latter remains green in color. Recent unpublished data of Mackinney of the University of California indicate that a more likely hypothesis is that the effect observed is caused by a physical change rather than a chemical one.

On severe oxidation, chlorophyll becomes white in color; green leaves and stalks such as the leaves and stalks of green oats or wheat left in the sun bleach to white in a few days under oxidation by the oxygen of the air and the catalytic action of sunlight. Apricots often contain some chlorophyll when first placed on trays to dry. If they are dried in the sun, the chlorophyll rapidly disappears, leaving only the golden-yellow color of the carotenoid pigments of the apricot. If dried in the dark, as in a dehydrater, the green color remains. The question arises, why does the chlorophyll disappear in the sun, even in the presence of 2,000 to 4,000 p.p.m. of sulfur dioxide, and remain when the fruit is dried in the absence of direct sunlight?

CAROTENOIDS

Like chlorophyll the carotenoids are plastid pigments, insoluble in water but soluble in fat solvents. They are widely distributed in fruits and vegetables, familiar examples being carotene, responsible for the yellow color of carrots, and lycopene, the red pigment of tomatoes.

A great deal of research, which is still in progress, has been conducted on the carotenoids by Kuhn and associates in Berlin, Zechmeister in Budapest, Karrer and associates in Zurich, and by Smith and associates of the Carnegie Institution of Washington at Stanford University, California.

Carotene.—The preferred present spelling is carotene rather than the former carotin. This pigment is of great importance biologically because in the animal body, probably in the liver, it is converted into vitamin A.

It has been prepared in crystalline form from widely diverse materials, including carrots, and is a normal constituent of all green leaves. In 1909 Escher obtained crystalline carotene by drying 5,000 kg. (over 5 tons) of carrots, extracting with petroleum ether, concentrating to a small volume and allowing the carotene to crystallize; the yield being less than 500 grams. It was purified by dissolving in carbon disulfide, precipitating and washing with aqueous alcohol and recrystallizing. Other methods have also been used.

Tswett made use of the fact that dry calcium carbonate adsorbs xanthophylls but not carotene. He packed a column tightly with powdered calcium carbonate and passed a petroleum-ether solution of the carotenoids through the column, which retained the xanthophylls and permitted the carotene to pass through. The various xanthophylls show somewhat different adsorption behavior, and the column after passage of the mixed carotenoids in solution shows a series of pink to rose adsorption bands. From the number of adsorption bands, their color, position, and appearance a rough qualitative estimate can be made of the number and kind of xanthophylls present.

Kuhn first utilized fuller's earth in the Tswett column; later he and Brockman prepared a highly active alumina, patented and sold by Merck's in Germany. Karrer developed a method with calcium hydroxide, as did also Miller at Chicago. The most satisfactory procedure in research laboratories on the Pacific coast consists in packing the Tswett column with a 1:1 mixture of magnesia and Hyflo Supercel, a diatomaceous earth used as a diluent—a technique devised by Strain and used also by Mackinney.

The carotenes have the molecular formula $C_{40}H_{56}$. They are unsaturated hydrocarbons containing 11 to 12 double bonds. They consist of eight isoprene nuclei. The formula for isoprene is

$$\begin{array}{l} H_2C{=}\underset{\displaystyle CH_3}{\underset{|}{C}}{-}CH{=}CH_2; \end{array}$$

that of the nucleus as encountered in carotene is

$$=\mathrm{CH}-\underset{\underset{\mathrm{CH_3}}{|}}{\mathrm{C}}=\mathrm{CH}-\mathrm{CH}=.$$

Three carotenes have been isolated, *viz.*, α- β-, and γ-carotenes. Beta-carotene can be hydrogenated to give $C_{40}H_{78}$, indicating the absence of a paraffin compound and the presence of two rings. The accepted formula today for β-carotene is that of a compound of a chain of conjugated double bonds as shown in the previous isoprene nucleus. The ionones and their stereoisomers have been known to perfumery chemists since 1893 as constituents of the essential oil of violets. Alpha-carotene has at one end of the molecule a ring identical with those of β-carotene and at the other end an α-ionone ring. It has an asymmetric carbon atom, and two of the hydrogen atoms have been shifted. Because of the asymmetric carbon atom, α-carotene is optically active, while β-carotene is not. On breakdown in the body, it yields only one molecule of vitamin A, *viz.*, from that half of the molecule containing the β-ionone ring, *i.e.*, α-carotene has only one-half the vitamin A potency of β-carotene. Gamma-carotene has one beta ring and one end of the molecule is open, *i.e.*, has no ring structure. Therefore, it also has only one-half the vitamin A potency of β-carotene. The structural details of the carotene molecules have been solved principally by the research of Kuhn in Berlin and by Karrer and associates at Zurich.

The absorption bands of the three carotenes as determined spectroscopically are characteristic and are useful in determining their presence, and in estimating them quantitatively.

For the structural formulas of the carotenes the reader is referred to modern texts on biochemistry or the references at the end of this chapter.

In carbon bisulfide solution, carotene is orange-red to deep red in color; in other solvents the color varies from yellow to golden yellow. It can be removed from 80 to 90 per cent alcohol, in which it is very slightly soluble, by shaking with carbon disulfide or petroleum ether, by which means it can be separated from polyhydroxy xanthophyll carotenoids.

Like other carotenoids it is readily oxidized, and on this account unsulfured dried cut fruits are usually low in vitamin A potency. For the same reason care should be exercised to avoid oxidation in extracting and concentrating carotene solutions.

The carotene content and vitamin A potency of butterfat are determined by the carotene content of the feed ration. The vitamin A potency of fruit juices is proportional to their content of carotene, and this is in turn proportional to the amount of water-insoluble pulp present, as carotene is not soluble in the juice.

Lycopene.—Lycopene is responsible for the red color of tomatoes. It is a hydrocarbon and has the same molecular formula as carotene, *viz.*,

$C_{40}H_{56}$, and is an isomer of carotene. It differs from β-carotene structurally in that the ends of the chain of carbon atoms constituting the molecule are open. Consequently it does not yield vitamin A in the animal body.

Lycopene is readily obtained in crystalline form from tomatoes by methods similar to those described for isolation and crystallization of carotene. From 74 kg. of tomato paste Willstätter obtained 11 grams of crystalline lycopene and a much smaller amount of carotene as a by-product. Both pigments are present in tomato fruit, although the color of the lycopene masks that of the carotene.

The crystals are dull brownish red to carmine in color and usually flake-like in form.

Like other carotenoids, lycopene is easily oxidized, being bleached thereby in color. Copper salts and iron salts, dissolved by tomato products from equipment, cause loss of lycopene and browning of the product. Prolonged heating of tomato products causes browning of the color also. The lycopene molecule has 13 double bonds. Its carbon disulfide solutions show, by the method of Kuhn, absorption bands at 548, 507.5, and 477 mμ when examined spectroscopically. In hot ether, alcohol, benzene, chloroform, and petroleum ether, lycopene solutions are yellow. In carbon disulfide they are deep pink-red, and the color persists on great dilution. Like carotene, it is removed practically completely from dilute alcohol solution by petroleum ether. The two pigments exhibit similar solubility in other solvents and are therefore difficult to separate. However, fractional crystallization as well as adsorption may be resorted to as a means of separation.

Since, as previously stated, the chain of the lycopene molecule is open at both ends, it does not yield vitamin A in the body. The high vitamin A potency of tomato products is due to other carotenoids, próbably chiefly carotene.

Other Carotenoids.—Karrer (1936) lists 30 carotenoids that have been definitely characterized. There are others that have been recognized spectroscopically.

The three basic carotenoid hydrocarbons, from which the other carotenoids are derived, are lycopene, α-carotene, and β-carotene. Most of the other carotenoids are hydroxy, methoxy, or keto derivatives of these hydrocarbons. These other carotenoids are by most authors designated xanthophylls. Cryptoxanthin is a 3-hydroxy-β-carotene; zeaxanthin, 3,3′-dihydroxy-β-carotene; rhodoxanthin, 3,3′-diketo-4,4′-dihydroxy-β-carotene; and xanthophyll (taken in its narrow sense), 3,3′-dihydroxy-α-carotene synonymous with Kuhn's lutein. Th relation of vitamin A, another derivative of a basic carotenoid, to β-carotene is evident from its formula, which is half that of β-carotene.

Rations rich in xanthophylls increase the color of egg yolk, red pimento powder being very effective in that regard. Carotene evidently does not have a similar effect. Xanthophyll-rich rations also have been found to color the flesh of White Leghorn chickens. Animal fats and vegetable oils are often colored by carotenoids, the source in both cases being plants.

As previously stated, use of the Tswett adsorption column charged with powdered magnesium oxide and infusorial earth or with calcium carbonate has provided a practicable means of separating the various xanthophyll pigments from carotene and from each other. Even very small quantities obtained in this manner can often be identified when the Tswett column is supplemented by spectroscopic examination.

The xanthophylls are more soluble than carotene in alcohol, this property providing another method of separation.

The xanthophyll of leaves is a relative of carotene. Its molecular formula is $C_{40}H_{56}O_2$ or $C_{40}H_{54}(OH)_2$. It is somewhat soluble in petroleum ether. It does not yield vitamin A in the body. Although xanthophyll (in its narrow sense) differs from carotene in containing two molecules of oxygen, oxidation of carotene *in vitro* does not yield xanthophyll. The molecule resembles that of carotene, except that each of the ring structures at each end of the molecule contains an OH group.

Cryptoxanthin has only one OH group, its formula being $C_{40}H_{55}OH$ or $C_{40}H_{56}O$. It has been found in yellow corn.

Zeaxanthin, $C_{40}H_{54}(OH)_2$, is an isomer of leaf xanthophyll. It is found in yellow corn and in a number of other plant materials. It is a dihydroxy compound.

Kuhn and Smakula have stated that lutein, the coloring matter of egg yolk, is a mixture of zeaxanthin and xanthophyll.

Another alcohol is rubixanthin, a derivative of γ-carotene. Its formula is $C_{40}H_{55}OH$. It has been isolated from *Rosa rubiginosa* and from the marsh dodder.

There are also keto derivatives of the carotenes. Rhodoxanthin, $C_{40}H_{50}O_2$, is a good example. The —C═O groups are in the ring structures at each end of the molecule; it is, therefore, a diketone. It has been isolated from red berries of yew.

The formula for capsanthin of paprika (*Capsicum annuum*) is according to Karrer, and also Zechmeister, probably $C_{40}H_{50}O_3$. It is usually present in paprika as an ester of some organic acid such as oleic, palmitic, stearic, etc. It is also termed capsorubin.

The saffron pigment, α-crocetin, is an acid, $C_{19}H_{22}O_4$, according to Karrer. Its molecule lacks the ring structures of carotene but contains the usual chain of isoprene nuclei of the carotenoids. Two other acid pigments related to the carotenoids are bixin and azafrin.

Certain fruits contain considerable quantities of phytoxanthins and carotene. Mackinney found in California dried Muir peaches and in fresh Lovell peaches β-carotene, cryptoxanthin, lutein, zeaxanthin, and a trace of α-carotene. He found no lycopene or γ-carotene, although he reports the presence of at least three additional carotenoids. Kuhn and Brockman report that the carotenoids of the apricot are chiefly β-carotene, γ-carotene, and lycopene, *i.e.*, principally hydrocarbon in nature, whereas the peach carotenoids are largely phytoxanthins.

ANTHOCYANINS, FLAVONES, AND TANNINS

The water-soluble red, blue, and violet pigments of blossoms, fruits, and leaves are anthocyanins. Willstätter in Germany established the constitution of these pigments and determined their general properties. The flavones are similar structurally to the anthocyanins, but lack the intense color of the latter.

Common Reactions of the Anthocyanins.—Several familiar reactions of the anthocyanins are the following: They are bleached temporarily by sulfur dioxide as in the treatment of red fruits for drying or by the addition of sulfur dioxide to crushed red grapes in wine making. On disappearance of the sulfur dioxide the color returns. A small concentration of sulfur dioxide protects the anthocyanin pigments against browning by oxidation and is used for that purpose in wine making. Prolonged heating injures the anthocyanin color of red juices and of canned fruits. Tin and iron salts dissolved from the tin plate by canned fruits either precipitate the anthocyanin pigments or cause them to become blue. These pigments act as catalysts in the corrosion of tin containers by fruits such as prunes, red cherries, red plums, and berries and therefore greatly hasten the production of hydrogen swells and perforations.

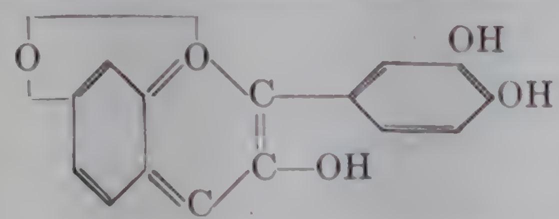
In strongly acid solutions they are red in color and in alkaline solutions usually blue. However, on addition of alkali to a red fruit juice, the color often becomes green instead of blue, owing to the combined color of the yellow of the flavones, so colored in alkaline solution, and of the blue of the anthocyanin. On oxidation in fruits or juices, the color changes from violet-red to brick red and eventually to brown. Thus, the color in very old wines becomes brown and the coloring matter rendered insoluble.

Solubility of Anthocyanins.—The anthocyanins occur in plants as glucosides and as long as they are in that form are water soluble. The glucosides are soluble also in alcohol and sometimes acetone but are usually insoluble in ether and other fat solvents.

Products of Hydrolysis of Anthocyanins.—On acid hydrolysis the sugar (usually glucose, rhamnose, galactose, or combinations of two sugars) is removed, leaving an anthocyanidin which is insoluble in water. It is soluble in alcohol from which it can be recovered in crystalline form.

Purification of Anthocyanins.—The earlier attempts to secure pure anthocyanins failed because the flavones were not removed. Willstätter and associates boiled flowers with water; filtered; precipitated anthocyanins, etc., with powdered lead acetate; decomposed the precipitate with dilute sulfuric acid; filtered off the lead sulfate; boiled under a reflux condenser with a dilute mineral acid to decompose the glucosides; cooled to allow anthocyanidins and flavones to separate as a brownish-red sediment; filtered; dried over calcium chloride; ground to a powder; extracted in a Soxhlet apparatus with ether to remove most of the flavones; dissolved the anthocyanidins in absolute alcohol; evaporated to a small volume; poured into a large volume of ether in which the remaining flavones dissolved and the anthocyanidins precipitated; filtered; dissolved in alcohol; and crystallized from alcohol. An alternative method consists in extracting the coloring matter from the plant or fruit tissue with glacial acetic acid; adding ether to precipitate the coloring matter; dissolving in water; adding picric acid, allowing the insoluble picrates to form; and subsequently decomposing the picrates with liberation of the anthocyanidins. Other methods are also available.

Structure of Anthocyanins.—Willstätter isolated and studied the pigment of bachelor's-button flowers, cyanin. He came to the conclusion that cyanidin, the pigment remaining after removal of the glucose by acid hydrolysis, is an inner oxonium salt of the following structure:



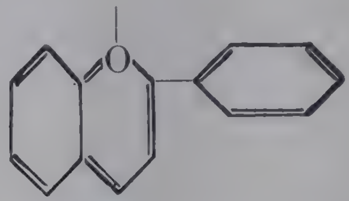
He determined that delphinidin, the pigment of larkspur flowers, is the same as cyanidin in structure except that it contains an extra OH group in the third ring. The anthocyanidin, pelargonidin, of scarlet geraniums was found to have one less OH group than cyanidin in the third ring. All other anthocyanin pigments studied by him were found to be derivatives of cyanidin, delphinidin, and pelargonidin.

For example, keracyanin of cherries is a rhamnoglucoside of cyanidin; idaein of cranberries is a monoglucoside of cyanidin; empelopsin, the red color of Virginia creeper berries, is a monoglucoside of delphinidin monomethyl ether; and oenin, the color of grapes of *Vitis vinifera*, is a monoglucoside of delphinidin dimethyl ether. Anderson and associates have found that the color of the skins of the American species of grapes, *viz.*, *V. labrusca*, *V. aestivalis*, and *V. riparia*, is a glucoside of a monomethyl ether of delphinidin; thus differing somewhat from the corresponding pigment of European grapes, *V. vinifera*, which is a dimethyl, or rather

dimethoxy, derivative. Anderson found that the color of crosses of *V. vinifera* and *V. labrusca* is a dimethoxy derivative; the *V. vinifera* color, therefore, being a dominant characteristic.

From the structure of the three fundamental anthocyanidins it can be seen readily that many different anthocyanins are possible.

A striking peculiarity of the anthocyanins is the presence of a tetravalent oxygen atom in the second ring structure; oxygen is nearly always divalent. The benzopyranol nucleus from which all the anthocyanidins can be derived by the introduction of additional hydroxyl or methoxy groups may be represented thus:



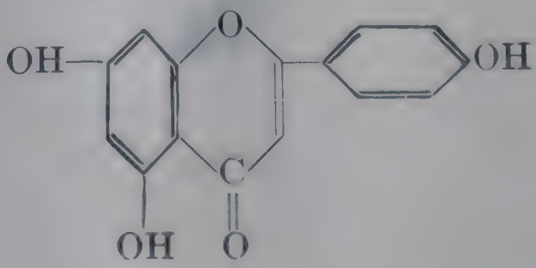
In this and other structural formulas of benzene ring compounds it is understood, of course, that there are carbon atoms at the corners and, where not otherwise indicated, hydrogen atoms attached to the carbon atoms.

Function of Anthocyanins.—The function of the anthocyanins in plants is still uncertain. They are easily oxidized and reduced, and on that account it has been suggested by Palladin and others that perhaps they are involved in respiration. However, this suggestion remains to be proved, according to Gortner.

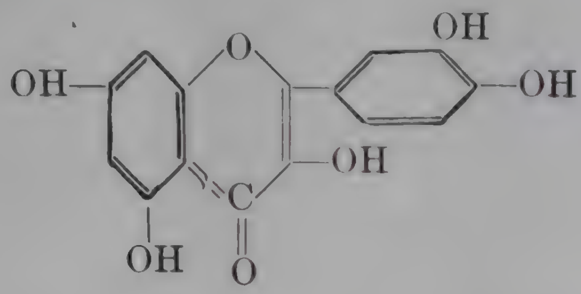
FLAVONES AND FLAVONOLS

These are yellow to colorless compounds closely related to the anthocyanins. They are very widely distributed in plant tissues, including the fruits. When colorless flowers are made alkaline with ammonia vapors or with sodium hydroxide the tissues become deep yellow in color, a reaction for flavones and flavonols, as well as for many other phenolic derivatives. They exist in the tissues as water-soluble and alcohol-soluble glucosides. The central nucleus is similar to that of the anthocyanins, except that the oxygen of the middle heterocyclic ring is divalent, not tetravalent, and the fourth carbon atom contains a C=O grouping. The flavones and flavonols are separated from the anthocyanidins as previously described.

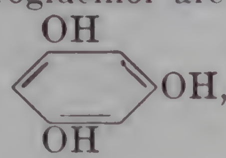
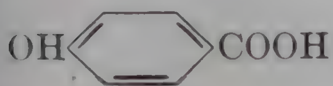
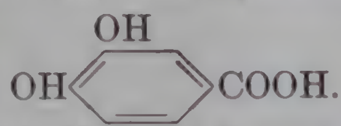
A typical flavone is apigenin,



and a typical flavonol is quercetin,



It will be noted that in the former the middle heterocyclic ring has no OH group, whereas in the flavonol it possesses one such group.

On acid hydrolysis of the glucosides the flavone or flavonol is split off as a water-insoluble substance, as previously stated. On alkaline hydrolysis of the flavones and flavonols, a hydroxy benzoic acid and usually phloroglucinol are produced. For example apigenin yields phloroglucinol,  and parahydroxy benzoic acid, ; whereas quercetin gives phloroglucinol and protocatechuic acid, .

Onslow suggests that the flavone glucosides may be converted into anthocyanins by oxidation; although this assumption is no longer considered correct.

Perkin and Everest have done a great deal toward determining the chemistry and general properties of the flavones and flavonols.

TANNINS

Distribution.—Tannin is of importance in wine, because it is responsible for part of the characteristic flavor of red wines and it aids in clarification by virtue of its property of forming insoluble precipitates with certain proteins such as gelatin. The astringency, "puckeriness," of dates and persimmons is due to the presence of tannins. During processing these fruits lose their astringency, probably by polymerization or oxidation, or both, of the tannins to an insoluble condition. Tannins are encountered in nearly all plants, notably in the leaves and bark. The leaves of oak, tea, chestnut, and sumac plants contain large amounts of tannin. Plant galls may contain 75 to 80 per cent of tannin on the dry basis. Some varieties of apples, notably crab varieties, are very rich in tannin. In fact most fruits give qualitative tests for tannins. The tannins of fruits have not been studied nearly so extensively as those of the various tannin extracts used in tanning hides.

While it is usually assumed that a greenish or bluish coloration with dilute ferric chloride indicates the presence of tannin, this reaction is not very dependable as it is given by a number of other plant compounds.

Common commercial sources of tannin are tan oak bark, sumac leaves, oak galls, *Uncaria gambier* (of Malacca, Penang, and Singapore, the extract being known as "cutch"), quebracho (of South America), divi-divi (see pods of *Caesalpinia coriaria*), and myrobalans (nuts of *Terminalia chebula*). Grape seeds are a common source of eno-tannin used in wine making.

General Properties.—The word tannin includes a large range of compounds that are not necessarily closely related. They are amorphous, therefore difficult to separate from other compounds of like solubility. Tannins are soluble in water, alcohol, acetone, and pyridine but insoluble in fat solvents such as ether, chloroform, etc.

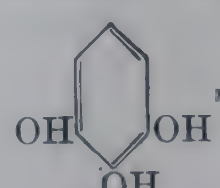
True tannins have the property of precipitating gelatin and converting the proteins of hides into leather. They are astringent, are easily oxidized, and give characteristic precipitates with salts of certain metals. They are all polyhydroxy phenols and, like simple phenols, give color reactions with ferric salts. They are precipitated by certain alkaloids.

In water, solutions of the tannins are colloidal in nature and exhibit the Tyndall effect when light is passed through the solution.

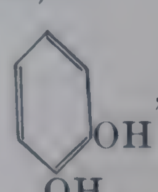
The tannins may serve as substrates for oxidase, *e.g.*, crushed green-walnut hulls blacken rapidly on exposure to air; and the surface of a cut apple turns brown rapidly, owing to oxidation of phenolic compounds, probably tannins.

Classification.—As previously stated, the tannins are a heterogeneous group of compounds and are amorphous, making it practically impossible to obtain them in pure form. Therefore, the structural formulas of most tannins are imperfectly understood. On this account it is not possible to characterize and classify them as satisfactorily as groups of compounds such as the sugars or organic acids.

The most common classification is that of Procter and others into pyrogallol and pyrocatechol tannins, *i.e.*, those that give pyrogallol,



and those that give pyrocatechol,



on alkaline hydrolysis. The pyrogallol tannins give a blue color and the catechol tannins a green color with dilute ferric chloride. The pyrogallol tannins give a precipitate with bromine water and the pyrocatechol tannins give none. There are also additional differentiating reactions to be found in Allen, "Commercial Organic Analysis," Procter, "Leather Manufacture," and other references.

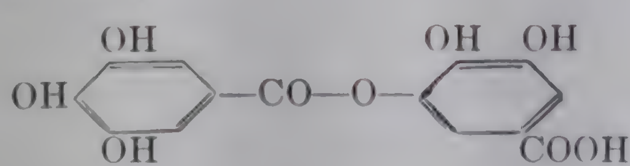
Russell advocates the classification of Perkin and Everest in which the tannins are divided into three groups:

I. Tannins related to depsides.
II. Tannins related to diphenyldimethylolid.
III. Phlobaphene-producing tannins (phlobatannins).

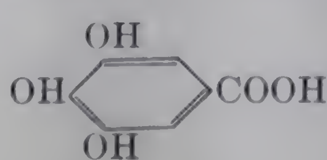
On boiling with dilute mineral acid the tannins of Groups I and II give crystalline compounds (gallic acid and glucose, and ellogic acid and glucose, respectively), whereas tannins of Group III are converted into brown or red, insoluble amorphous phlobaphenes. Freudenberg prefers to place I and II into one group, the hydrolyzable tannins, retaining Perkin and Everest's Group III, the phlobatannins. Tannins of Group I are found chiefly in pathological growths such as oak galls; Group II chiefly in certain nuts and pods; and Group III is a very large one containing the tannins of wood, bark, fruits, leaves, and roots. In fact, Russell states that Groups I and II contain only one member each at present. Therefore, he suggests that one might consider tannins as members of a single group, the phlobatannins, with Groups I and II as exceptional members.

Group I. *Depside Tannins.*—As previously stated only one natural tannin, gallotannin of plant galls, has been definitely placed in this group, although it contains also several tannins prepared synthetically.

Depside is a name coined by Emil Fisher to designate compounds formed by union of two or more molecules of phenolic acids. A typical depside is m-digallic acid,



Unaltered gallotannin is a glucoside containing five m-digallic acid nuclei, *i.e.*, it is pentadigalloyl-α-glucoside. On acid hydrolysis it yields nearly 1 molecule of glucose and 10 molecules of gallic acid,



E. Fisher synthesized penta-m-digalloyl-α-glucoside, which very closely

resembled the natural gallotannin. It is probable that natural gallotannin as usually prepared contains a considerable amount of products of its hydrolysis.

Group II. *Ellogitannin* (*Diphenyldimethylolid tannins*).—Ellagitannin, the only member of this group, is found in several plants, the commercial sources being myrobalans, algarobilla, divi-divi, and valonia. Since ellagitannin usually gives on hydrolysis ellagic acid and glucose, some authorities on the tannins consider ellagitannin a glucoside.

In the tanning of leather ellagitannin is much sought after because it leaves a "bloom" on the leather.

Group III. *Phlobatannins.*—These are the "iron greening" tannins. They are widely distributed in plants and in fruits. As previously stated, on boiling with dilute acid, they are converted into brown or red, amorphous water-insoluble substances termed phlobaphenes.

According to Russell they are related to the plant pigments of the benzopyran group, *viz.*, flavones, flavonols, and anthocyanins. They are also related to the flavans, of which catechin is the only known natural member. Catechin is found in small concentration in "cutch" ("catechu"), a tannin extract from the leaves and twigs of *Uncaria gambier*, from which it may be secured in crystalline form. A. G. Perkin solved its structural formula as a pentahydroxyflavan, a reduction product of quercetin, a well-known flavonol. Russell contends that the constitution of the phlobatannins is similar to that of catechin. He has synthesized compounds of known structural formulas that were qualitatively indistinguishable from the natural phlobatannins. Since the phlobatannins are amorphous and contaminated with various other plant compounds of like solubility and like reactions, it is extremely difficult to purify them sufficiently for satisfactory comparison with the synthetic compounds described by Russell.

Russell hydrolyzed hemlock tannin (a phlobatannin) with fused alkali and obtained pyrogallol, protocatechuic acid, and pyrocatechol. Mimosa tannin from South African wattle bark gave phloroglucinol, protocatechuic acid and pyrocatechol. Other phlobatannins give on alkali fusion one or two polyhydroxyphenols (phloroglucinol, resorcinol, pyrogallol, or pyrocatechol) and a phenolic acid (protocatechuic or gallic). Pyrocatechol is formed by decarboxylation of protocatechuic acid, and pyrogallol similarly from gallic acid. It is possible that two or more molecules of the pentahydroxyflavans may be combined in some phlobatannins.

Russell made a detailed study of the properties of phlobatannins, in which, as previously mentioned, he synthesized compounds, *viz.*, polyhydroxyflavpinacols, that proved indistinguishable from certain natural phlobatannins as judged by exact absorption spectra measurements and

by qualitative reactions. He states, on the basis of this work, that the phlobatannins are not related to the depsides but are polyhydroxyflavpinacols derived from the corresponding 4-hydroxyflavans; and are related to the plant pigments of the benzopyran type (flavones, flavonols, and anthocyanins) rather than to the classic pyrogallol tannin of Fischer.

Other Substances Classified with Tannins.—From coffee beans has been extracted a substance called caffetannin. It does not precipitate gelatin and, therefore, is probably not a true tannin. On hydrolysis it gives quinic acid, caffeic acid, and a residue of unknown composition. Caffetannin is usually associated with chlorogenic acid, which H. O. L. Fischer has proved to be a compound formed by the union of caffeic and quinic acids. Russell believes that caffetannin is probably closely related to, or may be identical with, chlorogenic acid. There is evidence to indicate that chlorogenic acid occurs in prunes and several other fruits.

Catechin, as previously discussed, is closely related to the phlobatannins.

Various hydrolyzable plant products have been grouped with the tannins. Some precipitate gelatin, as do a number of nontannin plant substances. Acertannin is found in the leaves of Korean maple. It is crystalline and is said to give one molecule of aceritol and two molecules of gallic acid on hydrolysis. Hamameli tannin also is crystalline and gives, on acid hydrolysis, gallic acid and a hexose. Russell states that it is unlikely that these are true tannins.

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CHAPTER XXXIV

ENZYMES OF FRUITS AND VEGETABLES

Enzymes are of considerable importance in the preparation and preservation of fruit and vegetable products. For example, vitamin C is rapidly destroyed in freshly expressed unheated tomato juice, apple juice, and certain other juices owing to the presence of ascorbase, an enzyme that catalyzes oxidation of ascorbic acid (vitamin C). Fruits darken during sun drying owing to the action of oxidizing enzymes. They decrease in jellying power on becoming overripe, or if allowed to stand after crushing, because of action of pectolytic enzymes. Yeast fermentation is, of course, a classic example of a set of reactions involving enzyme action. In the processing of dates and persimmons, tannin is converted into a nonastringent condition by enzyme action. Enzymes cause undesirable changes in flavor and odor in frozen-pack fruits and vegetables. Pectin-splitting enzymes are utilized in the clarification of fruit juices. Other examples could be given.

The present knowledge of the subject of enzyme behavior, chemistry, occurrence, and general properties is so extensive and varied that it can not be treated in very great detail in this chapter. Attention will be given principally to those portions of the field that are of most interest to students and producers of fruit and vegetable products.

Definition.—An enzyme is sometimes defined as a heat-labile catalyst, elaborated by living cells, yet capable of acting independently of the life processes of the cell. For example, invertase is an enzyme secreted by living yeast cells. It can be isolated from yeast by suitable means and will still retain its power of catalyzing the inversion, *i.e.*, hydrolysis, of cane sugar into levulose and dextrose. It is rendered inactive by heating a short time at 80 to 100°C., *i.e.*, it is heat labile. In this respect it and other enzymes differ from simple chemical catalysts such as platinum black, manganese dioxide, etc., which are not destroyed by heating at or below 100°C.

It is generally considered that, in aqueous solution at least, enzymes are either themselves colloidal in nature or bound to a colloidal carrier.

While, perhaps theoretically, an enzyme merely catalyzes on existing reaction, practically it also initiates the reaction. For example in a pure cane sugar solution there is no detectable change to invert sugar; but if invertase is added, the inversion is initiated and proceeds rather rapidly, and its rate is easily measured.

Specificity of Enzyme Action.—Inorganic catalysts are usually capable of catalyzing a number of very different reactions. On the other hand enzymes are usually limited to the catalysis of a single reaction, or group of similar reactions.

For example, invertase can bring about the hydrolysis of sucrose (cane sugar) but cannot similarly affect lactose (milk sugar) or maltose (malt sugar), although these other two sugars have the same empirical formula as cane sugar, $C_{12}H_{22}O_{11}$, and are both disaccharides (yield two hexose sugars on hydrolysis).

Emulsin, an enzyme found in almond kernels, peach leaves, and other plant parts, is capable of causing the hydrolysis of amygdalin of bitter almonds and of apricot kernels into dextrose, hydrocyanic acid, and benzaldehyde. Amygdalin is a β-glucoside as are most other naturally occurring glucosides. It is an interesting fact that emulsin attacks many other natural glucosides that yield very different end products on hydrolysis than those from amygdalin, because the sugar linkage in the glucoside molecule is similar to that of amygdalin. However, emulsin is restricted in its action to the β-glucosides; it does not attack pectin, or olive oil, or proteins; nor do protein-splitting enzymes attack carbohydrates or oils. On the other hand lipase is not limited in its action to one kind of oil (one form of glyceride) but will catalyze the hydrolysis of all common vegetable oils.

Tyrosinase, an enzyme found in potatoes, catalyzes the oxidation of tyrosine and catechol but will not attack guaiacol. All are phenolic compounds. Laccase, another oxidizing enzyme of plants, attacks guaiacol and catechol, but not tyrosine.

In other words enzymes are restricted in action to a single substance or to a group of closely related substances.

Classification of Enzymes.—Enzymes may be classified according to the nature of the substrate (the substrate being the substance acted upon), or according to the character of the transformation induced by the enzyme. Thus, we have, according to the former system, such enzymes as proteases, sucrase, pectinase, and so forth; according to the latter system we have hydrolytic enzymes, oxidizing enzymes, reducing enzymes, zymases, etc.

The following classification, or list, of the more important enzymes is convenient for purposes of comparison and discussion. In the interest of brevity a number of the less important enzymes have been omitted.

1. Hydrolytic enzymes.
    - *a*. Sugar-inverting enzymes, *viz.*, invertase, maltase, and lactase.
    - *b*. Pectolytic enzymes (pectase and pectinase).
    - *c*. Protein-splitting enzymes (proteases) such as pepsin, trypsin, papain, bromelin, etc.

   d. Lipases, fat-splitting enzymes.
   e. Diastases, starch-splitting enzymes of cereals, molds, of other plants, and of certain digestive juices of animals.
   f. Tannases, tannin-splitting enzymes of microorganisms and of plants.
   g. Beta-*glucosidases* (emulsin). Emulsin of almonds and leaves. Hydrolyzes natural glucosides.
   h. Alpha-glucosidase (maltase). Hydrolyzes maltose and other α-glucosides.
   i. Urease. Found in jack beans. Converts urea to ammonium carbonate.
   j. Miscellaneous, such as arginase and others.
2. Oxidizing enzymes.
   a. Peroxidases.
   b. Dehydrogenases.
   c. Oxidases (complete oxidases of plants, consisting of peroxidase, organic peroxide, and oxygenase). Otherwise termed phenolases.
3. Reductases; reduce methylene blue and certain other substances. Equivalent to dehydrogenases.
4. Catalase. Splits oxygen from hydrogen peroxide. Closely related to oxidizing enzymes.
5. Zymase of yeast; converts hexose sugar into alcohol and carbon dioxide. This term has also been applied to other enzymes causing decomposition of molecules other than by hydrolysis.
6. Mutases. Cause chemical rearrangement in molecules without splitting them into smaller molecules, oxido-reductases.
7. Clotting enzymes. Rennin of calves' stomach, the milk clotting enzymes of certain bacteria, and thrombin or thrombase, the blood clotting enzyme of blood.

Temperature Relationships.—The velocity of enzyme action is greatly affected by temperature. Within certain temperature limits the velocity is increased by rise in temperature until an optimum temperature is reached; further increase in temperature causes a decrease in velocity until the inactivation temperature, at which the enzyme is rapidly destroyed, is attained. The optimum temperature is affected by hydrogen-ion concentration, ratio of substrate to enzyme, and by other factors. Thus if there is a small amount of enzyme and a large amount of substrate, the optimum temperature is apt to be lower than if there is a large amount of enzyme and a small amount of substrate, since in the optimum temperature range inactivation of the enzyme by heat may be fairly rapid. Therefore, in the former case the rate of enzyme destruction may exceed that of enzyme action on the substrate, whereas in the second case the reverse may be true. In other words, in any definition of

optimum temperature, experimental conditions in respect to pH value, as well as concentration of enzyme and substrate, must be specified.

For most enzymes the optimum temperature lies between 40 and 50°C., but there are a number that have a temperature optimum in the neighborhood of 60°C.

The temperature coefficient between the temperature at which the enzyme is rapidly destroyed and the lowest temperature at which the reaction is appreciable, is fairly constant. For most enzymes an increase of 10°C. (18°F.) causes the reaction velocity to increase 2 to 3 times. A common method of designating this coefficient is by the ratio $K_{t \times 10}: K_t$. For several well known enzymes the following values have been obtained by various investigations: lipase, 18 to 28°C., 2.6; invertase, 0 to 20°C., 2.0; zymase, 15 to 25°C., 2.8; diastase, 30 to 40°C., 2.0; catalase, 0 to 10°C., 1.5; trypsin on casein, 20 to 30°C., 5.30; emulsin on salicin, 20 to 30°C., 2.0, *i.e.*, between 20 and 30°C. an increase of 10°C. doubles the velocity of hydrolysis of salicin by emulsin.

Beyond the optimum temperature the rate of inactivation of enzymes by heat rapidly increases. The so-called "inactivation temperature" for enzymes is, however, a rather indefinite entity, as it depends upon the pH value of the medium, upon whether the enzyme is in solution or dry, and upon the length of the heating period. One method of determining the inactivating effect of heat on enzymes is that of ascertaining the temperature at which it loses one-half of its activity in 1 hr., when heated in aqueous solution at the optimal pH value in the absence of the substrate. Another, and perhaps more convenient, method is that of determining the minimum temperature at which all activity is destroyed in 5 min. or in 10 min. The writer has used the latter method in studying the effect of pH value on the inactivating temperature of phenolase of fruits.

In solution at the optimal pH value of the enzyme and in the absence of substrate the inactivation temperature for most enzymes, heated for a period of 5 min., lies between 70 and 80°C. For example, the peroxidase of most fruits is destroyed at 80°C. in 5 min. or less at a pH value of 4.0 or less when the enzyme is heated in the juices of the respective fruits. For example the peroxidase of clingstone peaches was destroyed in 2 min. at 70°C. at pH 4.2, and at 90°C. in 2 min. at pH 5.25 (determined by P. J. Quin in this laboratory).

At temperatures below 40°C. most enzymes are fairly stable, but at temperatures above 50°C. inactivation is usually rapid.

✓ Some enzymes after inactivation by temperature regain part of their activity on subsequent storage at low temperatures. Such observations have been reported for the diastase of the mold *Aspergillus oryzae*, certain oxidizing enzymes, invertase, and trypsin.

The rate of destruction, naturally, varies with the temperature; the higher the temperature the more rapid the rate of destruction.

The rate of reaction relationship for most enzymes follows the well known monomolecular equation for chemical reactions and may be expressed as follows:

$$\frac{dy}{dt} = K_a(F - Y)$$

where F represents the original enzyme concentration or activity, and Y the concentration or activity at time t. On integration this equation becomes,

$$K_a = \frac{1}{t} \ln \frac{F}{F - Y}$$

Waldschmidt-Leitz ("Enzyme Action and Properties") expresses the relationship as follows:

$$K_c = \frac{1}{t} \ln \frac{K_a}{K_t}$$

where K_a is the original reaction velocity, K_t is the velocity after t min. of heating, and K_c is a constant. K_c should be constant, if the equation is valid. Waldschmidt-Leitz gives the following values for K_c for heating of emulsin at 60°C.: 15 min., 0.76; 30 min., 0.88; 45 min., 0.83; and 60 min., 0.75.

In the dry condition enzymes are much more resistant to heat than when in solution; some have withstood 100 to 120°C. for considerable periods in the dry state.

Enzymes also exhibit minimum temperatures at which activity ceases or becomes extremely slow. Some enzymes, however, such as those responsible for undesirable changes in odor and flavor in frozen-pack vegetables, cause marked changes in these qualities in the frozen products stored at temperatures considerably below 0°C. It is for that reason that vegetables to be preserved by freezing storage are blanched in steam or hot water for a sufficient time to destroy the enzymes responsible for the changes indicated.

Role of Hydrogen-ion Concentration.—Enzymes are greatly influenced by the reaction (hydrogen-ion concentration, pH value) of the medium. As with temperature, there are optimum, minimum, and maximum pH values for the activity of enzymes, these values differing according to the enzymes. The variation among enzymes in respect to optimum pH value is indicated by the following values for several important enzymes. The optimum pH value for the diastase from *Aspergillus oryzae* has been reported as 4.8; diastase of malt, 4.3 at 25°C. and 6.0 at 69°C.; diastase of animal pancreas, 7.0; diastase of saliva, 6.1 to 6.2; carboxylase of yeast, 5.3 to 6.2; emulsin of almonds, 4.0 to 5.3; invertase of yeast, 4.2 at 22.3°C.; lipase of castor bean, 5.0; pectase

of fruit, 4.3; pepsin of the stomach gastric juice, 1.2 to 1.6, depending upon the protein used; peroxidase of vegetables, 7 to 10; peroxidase of apricots, about 5.0; trypsin of pancreas on casein, 8.3; tyrosinase (potato oxidase), 6.5 to 8.0; and zymase of yeast, 4.5 to 6.5.

Some enzymes exhibit a plateau for optimum pH value, *i.e.*, a range over which maximum activity prevails, *e.g.*, 6.5 to 8.0 for potato tyrosinase. As previously stated, the optimum pH value of most enzymes varies with temperature for the reason previously given (see page 757). The presence or absence of certain compounds affects the optimum pH, *e.g.*, the optimum pH for saliva diastase in phosphate, acetate, or sulfate mixtures has been reported at 6.1 to 6.2 and in chloride and nitrate mixtures at pH 6.9. For pancreatic diastase in a phosphate buffer solution the optimum pH is 7.2 and in acetate buffer, 5.6.

As indicated in a preceding paragraph, enzymes from different sources and which catalyze the same reaction often differ greatly in their pH optimum. For example the optimum pH for peptase from the gastric juice of higher animals is about 1.5, for that from yeast 4.0 to 4.5, and for that from malt 3.7 to 4.2.

As previously mentioned the heat-inactivation temperature is markedly affected by pH value. For example, in experiments made by Quin in this laboratory partially purified peach peroxidase was destroyed by 2 minutes' heating to 60°C. at pH 3.25; to 65°C. at pH 3.8; to 70°C. at pH 4.2; to 75°C. at pH 4.5; and to 90°C. at pH 5.25. At pH 2.0 and pH 11 it was rapidly inactivated at room temperature.

Effect of Radiation.—The short wave lengths of light, particularly those of the ultraviolet range, exert a destructive effect on some enzymes. Ultrasonic radiation rapidly destroys the peroxidase of fruits. X rays appear to be less destructive than ultraviolet on enzymes. Radium emanations are reported to stimulate certain enzymes, to have no effect on others, and to slightly weaken others.

It is probable that some of the destructive effect of ultraviolet is due to action of the ozone and hydrogen peroxide formed during radiation of aqueous solutions.

Accelerators and Inactivators.—The activity of many enzymes is increased by the presence of certain substances and the activity of many is retarded or destroyed by certain substances.

The salts of the heavy metals are strong inhibitors of enzyme action. For example, 1 part of mercuric chloride in 200,000,000 will greatly reduce the activity of catalase. Silver, gold, copper, nickel, cobalt, and iron salts are also toxic to most enzymes.

Certain organic substances injure some enzymes; catalase, for example, is greatly inhibited by a trace of hydrocyanic acid. Papain, on the other hand, is stimulated by it, and pepsin is scarcely affected

Formaldehyde inhibits most enzymes, perhaps, by forming insoluble protein compounds. Sulfurous acid greatly retards and, in sufficient concentration, prevents the activity of fruit and vegetable oxidases. Alcohol may be used to precipitate some enzymes without serious injury; other enzymes are to a large degree inactivated by such treatment. Sodium fluoride paralyzes lipase and fruit peroxidase.

Traces of manganese salts greatly accelerate the action of some oxidizing enzymes. Phosphates stimulate certain enzymes, notably zymase of yeast. Alkali salts stimulate diastase; and amino acids protect it against hydrolysis. Ethylene gas bubbled through a yeast zymase preparation greatly prolongs its life.

Accumulation of the products of enzyme hydrolysis retards the activity of the enzyme concerned. The addition of invert sugar solution (dextrose and levulose) to a solution of cane sugar and invertase retards the velocity of inversion. Inversion of starch by malt diastase is retarded by addition of maltose. Both of these cases are examples of the mass action law of chemistry.

Endoenzymes and Exoenzymes.—At one time it was believed that enzymes could be grouped as endoenzymes and exoenzymes (those that are secreted in solution or are freely soluble from the cells). It is impossible to draw a fixed line of demarcation, although the division into enzymes that are dissolved readily from the cells by water, plant juice, or sap and those that cannot be dissolved in this manner from the cell holds in a general way.

Diastase of barley malt is readily dissolved from the ground malt. On the other hand invertase of yeast is bound to the cell contents and is not dissolved until action of proteolytic enzymes liberates it. Peroxidase of fruit tissue dissolves to a limited extent only in water or in dilute acids but dissolves freely in dilute alkali such as dilute sodium bicarbonate. In this case it is probably adsorbed on fruit colloids and is liberated by the alkali.

Coenzymes and Activators.—When certain enzymes are dialyzed, they are separated into two substances, both of which are inactive; but activity is regained if the two are recombined. Thus if yeast juice prepared by the method of Buchner is dialyzed or filtered through a gelatin filter, the colloids left behind are inactive and can be destroyed by heat. The substance that passes through the dialyzing membrane or gelatin filter is noncolloidal and is heat stable. If the substances which have passed through the membrane or ultrafilter are mixed with the residual colloids the enzyme activity is regained. The substance that passes through the membrane is spoken of as the coenzyme. In this case the principal coenzyme is a complex phosphate. Lipase of liver requires as coenzyme sodium cholate or glycocholate.

Various enzymes are secreted in the inactive state and require activation by some specific substance. In the inactive condition they are known as zymogens or proenzymes. Trypsinogen is secreted by the pancreas into the duodenum where it meets enterokinase, a complex substance that activates it. Before activation it will not appreciably attack proteins but after activation rapidly hydrolyzes them. Pepsin is secreted as pepsinogen and is activated by the hydrochloric acid of the stomach. Papain activity is increased by hydrocyanic acid. For coagulation of pectic acid, pectase requires a calcium salt.

Equations.—Since so many conditions may affect the velocity of enzyme action, exact mathematical formulations usually do not apply very closely. The velocity may decrease during the course of the reaction because of irreversible destruction of the enzyme by heat or other agents; of changes in pH value; of inhibiting effect of the products of reaction; of union of part of the enzyme with substrate or reaction products to form an inactive compound; and of other factors.

If, however, such inhibiting or retarding effects are small, the reaction velocity may approximate that of a monomolecular reaction, *viz.*,

$$\frac{dx}{dt} = k(a - x)$$

or on integration

$$k = \frac{1}{t} \ln \frac{a}{a - x}$$

where k is the velocity constant, a the original concentration of substrate and $(a - x)$ the amount of unchanged substrate at the end of time t. Expressed in terms of log 10 instead of the natural logarithm ln, the equation becomes

$$0.434k = \frac{1}{t} \log \frac{a}{a - x}$$

In the inversion of cane sugar by invertase, sucrose is hydrolyzed to dextrose and levulose; the reacting compounds are sucrose and water. Since the concentration of the water remains practically constant, it may be neglected. Therefore, the change is essentially that of sucrose alone, and should obey the monomolecular reaction equation. At temperatures that do not inactivate the invertase the value of K is reasonably constant. Usually the enzyme concentration is extremely low and does not change greatly during the reaction under favorable conditions.

Colloidal Nature of Enzymes.—Although several enzymes have been prepared in crystalline form, in water all enzymes, either of themselves or in union with a colloidal carrier, form colloidal solutions, which are

suspensions of particles of ultramicroscopic size. Like other colloids, they have enormous surface area in relation to the weight present in solution, which accounts in part for their great activity and power of adsorption. Often they possess an electrical charge, which depends upon the ion with which they are combined or upon the reaction (alkalinity or acidity) of the solution. Therefore, under the action of a direct current they travel toward the pole of opposite charge; although electrical transference may be due in many cases to accompanying impurities.

Invertase is adsorbed by electropositive adsorptive agents such as ferric hydroxide and aluminum hydroxide. Adsorption is a common characteristic of colloids. Enzymes are frequently purified by adsorption on kaolin or an aluminum hydroxide, followed by elution (dissolving) by a solution of suitable reaction. Those adsorbed by the electronegative substance kaolin may be regarded as positively charged; those adsorbed by aluminum hydroxide may be regarded as negatively charged; and those adsorbed by both could be considered as amphoteric.

Enzyme solutions, even when highly purified, exhibit the Tyndall effect, *i.e.*, if a beam of light is passed through the solution at a right angle to the line of vision, its path through the solution is readily visible, because of diffraction of the light by the colloidal particles.

It is often difficult to separate the properties of the enzyme itself from those of other colloids that may act as carriers in some cases, or which may be present as impurities.

Purification of Enzymes.—As enzymes occur in fruits and vegetables in their natural state, they are accompanied by many substances that affect their activity or interfere with methods of measuring enzyme action. Consequently for certain kinds of investigations, it is desirable to separate the enzyme from accompanying substances. Various procedures have been used.

One common method of concentrating the enzymes of plant tissues consists in grinding and pressing the fresh material to secure a juice or sap containing the enzyme. To this liquid are added several volumes of 95 per cent ethyl alcohol which precipitates the enzymes together with pectin, gums, certain proteins, etc., leaving sugars, organic acids, and other simple compounds in solution. The coagulum is pressed, again suspended in water, and precipitated a second time with alcohol. The precipitate is usually much more active than the original juice.

Enzymes may be salted out of solution by saturating the juice or extract with ammonium sulfate. The enzymes precipitated either by alcohol or by salting out can be further purified by dialysis, *e.g.*, by placing the solution in a collodion bag or inside other dialyzing membrane, and dialyzing against distilled water. Electrolytes and compounds of low molecular weight are removed by diffusion through the membrane.

Enzymes can often be purified further by adsorption on aluminum hydroxide, fuller's earth, or charcoal at suitable pH value and eluting subsequently with dilute alkali.

A convenient method of preparing a peroxidase of high activity from fruits and vegetables consists in grinding the fresh material finely; adding 3 to 4 volumes of 95 per cent alcohol to precipitate the enzymes and to extract sugars, etc.; washing with 80 per cent alcohol; extracting in the cold with 1 per cent sodium bicarbonate solution; acidifying the latter; precipitating the enzymes with 95 per cent alcohol; expressing the latter from the coagulum and suspending in a suitable volume of phosphate or citrate buffer solution of pH 4 to 5.

Several enzymes have been prepared in crystalline form. In 1926 Summer reported the isolation of crystalline urease. He extracted defatted, jack bean meal with 31 per cent acetone and held the solution at a low temperature until colorless, octahedral crystals were obtained. The substance was recrystallized without loss of activity. It was reported to have about 730 times the activity of the most active jack bean meal.

Northrop in 1930 reported the preparation of pepsin in crystalline form by precipitating the enzyme out of dilute sulfuric acid solution by addition of saturated magnesium sulfate solution; by dissolving in dilute alkali; by precipitating with acid; by redissolving in warm alkali; and by allowing the solution to cool very slowly.

In 1932 Northrop and Kunitz published a paper on the preparation of crystalline trypsin. It was secured by adding saturated ammonium sulfate solution to a concentrated solution of trypsin in one-fourth saturated ammonium sulfate and allowing the solution to stand.

The three enzymes were protein-like in nature, containing about 15 per cent of nitrogen. Each contained approximately 1 per cent of sulfur.

Early in 1937 Summer and Dounce announced the successful preparation of catalase in crystalline form from liver.

Recently a crystalline flavine has been isolated from yeast, milk, egg white, and other sources and has been proved not only to be a vitamin of the G group, but also an extremely important component of an oxidizing enzyme complex. Warburg and Christian in 1932 reported the isolation of this oxidation enzyme from bottom yeast. It acts as a catalyst, taking up hydrogen from the substrate and thereby changing in color from yellowish red to colorless. Oxygen regenerates the colored form. The enzyme can be split by treatment with methyl alcohol into a protein carrier insoluble in alcohol and a phosphorus-containing flavine closely related to lactoflavine, of the vitamin G complex. The flavine by itself can also act as a hydrogen acceptor. Theorell and others have purified the "yellow ferment" of Warburg and have separated the flavine

and the protein carrier by dialysis. The yellow ferment has been crystallized and its molecular weight estimated at about 70,000. It is of peculiar interest that a vitamin B_2 (or G) and an enzyme, Warburg's yellow ferment, have been found to be so closely connected, the flavine of the latter being also the vitamin (except for the fact that it contains phosphorus, which can be removed).

Mechanism of Enzyme Action.—Several explanations of the manner in which enzymes bring about transformations have been proposed. The leading theories agree on the assumption that an intermediate compound of substrate and enzyme is formed as is true of other catalysts.

According to the theory of Michaelis the enzyme and substrate combination is formed by an ionic reaction. It assumes that the reacting substances are present in homogeneous solution and also postulates that there is not only combination of substrate and enzyme but also of the reaction products and the enzyme. The latter postulate would tend to explain the well-known fact that the reaction products retard the rate of reaction.

On the other hand the theory of Bayliss is based upon the colloidal properties of enzymes. He considers that the substrate is first adsorbed in specific manner by the enzyme and that adsorption precedes and makes possible the subsequent chemical reaction. There is, therefore, great increase in concentration of the reacting substances on the colloid particle (the enzyme particle) owing to adsorption. Reaction occurs at the interface between components of a heterogeneous system.

The reaction velocity is dependent upon the substrate concentration, *i.e.*, the mass action law applies within certain limits. At very high concentrations the velocity is retarded. Also reaction velocity is proportional to the enzyme concentration. For a given enzyme, the Michaelis constant K_m is the substrate concentration at which half the limiting or maximum velocity of reaction is attained. It is characteristic of each enzyme and is useful in certain mathematical considerations of enzyme action.

HYDROLYTIC ENZYMES

The hydrolytic enzymes comprise an important and very large and varied group. It is not possible, owing to limitation of space, to consider all of the important members of this group adequately in this chapter; consequently principal attention will be given to those hydrolytic enzymes of greatest interest to students of fruit and vegetable products.

Invertase.—This enzyme has been studied very extensively. It is also known as saccharase, invertin, and as an α-fructosidase. It converts sucrose (cane or beet sugar) into glucose (dextrose) and fructose (levulose); these other sugars being known also as "grape" sugar and "fruit"

sugar, respectively. The equimolecular mixture of dextrose and levulose is commonly known as "invert sugar." The reaction is

$$\underset{\text{Sucrose}}{C_{12}H_{22}O_{11}} + \underset{\text{water}}{H_2O} \rightarrow \underset{\text{dextrose}}{C_6H_{12}O_6} + \underset{\text{levulose}}{C_6H_{12}O_6}$$

Invertase is found in abundance in yeast, which is the commercial source of invertase preparations used industrially. It occurs also in green leaves, fruits, grains, potatoes, in various fungi, certain bacteria, and in various animal tissues.

The enzyme is readily prepared from compressed yeast by autolysis (self-digestion) in the presence of water and an antiseptic such as toluene (to prevent putrefaction), filtration, and precipitation with alcohol followed by drying; or by adsorption on aluminum hydroxide followed by extraction with dilute alkali and precipitation with alcohol and drying. There are several other ways of preparing active invertase concentrates (see Waksman and Davison). It is an endoenzyme tightly bound to the cell contents; hence autolysis or other means of breaking up this combination must be employed before much of the enzyme can be dissolved from the yeast cells.

Invertase is used industrially in candymaking by adding it to fondant which is then coated with chocolate. The invertase converts some of the cane sugar to invert sugar (dextrose plus levulose) which dissolves to give a syrupy mass of sufficiently high sugar concentration to prevent fermentation of the candy centers by yeasts or bacteria. The fondant is also softened to a more desirable consistency by the partial inversion. In the processing (artificial ripening) of dates much of their cane sugar is hydrolyzed to dextrose and levulose by the invertase occurring naturally in the fruit. It also brings about the same change in sucrose in many other fruits.

The progress of inversion of cane sugar solutions by invertase can be followed by means of a polariscope, since cane sugar solutions are dextrorotatory and invert sugar solution is levorotatory in its effects on the polarized light beam used in polariscopes. This method is rapid, convenient, and accurate. Cane sugar does not affect Fehling solution (alkaline tartrate-copper sulfate solution), whereas invert sugar (dextrose plus levulose) reduces it, changing cupric ions to cuprous with precipitation of red cuprous oxide. The reduction is quantitative and provides a chemical means of following inversion of the sucrose.

The rate of inversion follows the monomolecular law:

$$0.434K_1 = \frac{1}{t} \log \frac{a}{a - x}$$

or

$$K_2 = \frac{1}{t} \log \frac{100}{100 - x}$$

where $K_2 = 0.434\ K_1$, and x is the percentage of inversion in time t. The values for K are remarkably constant.

The optimum pH range for yeast invertase is approximately 3.5 to 5.5 with maximum activity at about pH 4.5. Invertase of honey has an optimum pH range of 5.5 to 6.3. The optimum temperature is about 52°C. High concentration of invert sugar retards the velocity of hydrolysis.

It is probable that there are several invertases, their nature differing according to the source.

Maltase.—This enzyme converts maltose, $C_{12}H_{22}O_{11}$, into two molecules of dextrose $C_6H_{12}O_6$. It occurs in barley malt, most yeasts but not all, many fungi, in small amounts in plant tissues, in intestinal secretions, and in certain other secretions. It is of importance in brewing operations, since it converts into dextrose much of the maltose formed by diastase. For research purposes it is prepared from yeast. It is very unstable.

In addition to maltose it is able to hydrolyze other α-glucosides. However, most of the naturally occurring glucosides are β-glucosides, hence not attacked by maltase.

Lactase.—This enzyme rarely occurs in yeasts and on that account milk sugar, lactose, is not fermentable by the common industrial yeasts, such as wine yeasts, bread yeasts, and beer yeasts. Certain yeasts, such as *Saccharomyces fragilis*, however, possess lactase and can be used as a source of the enzyme. It can also be obtained by maceration of the small intestine of suckling animals previously fed on lactose. Many bacteria also contain lactase.

It is of interest to us primarily in connection with the possible alcoholic fermentation of milk by certain yeasts and of whey, a by-product from cheese factories.

Diastases.—The enzymes that hydrolyze starch and glycogen to maltose are called diastases or amylases. They are widely distributed in plant and animal tissues being particularly abundant in the seeds of cereals during germination. Many Fungi, but particularly the Aspergilli and Mucorales contain it; one of the most important industrial diastase preparations is Takadiastase made from *A. oryzae*. Salivary diastase secreted in the mouth contains an active starch-splitting enzyme known as "ptyalin." The diastases of plant origin differ markedly in general properties from those of animal origin.

Malt diastase may be prepared by grinding dried malt (sprouted, dried barley used for brewing), extracting with water, concentrating *in vacuo*, and precipitating with alcohol. It can be further purified by redissolving in water, filtering, reprecipitating with alcohol, and then dialyzing to remove compounds of low molecular weight.

Mold diastase may be prepared by growing *A. oryzae* on sterilized, steamed rice, extracting the mycelium with water, and precipitating the enzyme with alcohol or saturating the solution with ammonium sulfate. Malt and *A. oryzae* are the most common sources of diastase.

The mold diastase is very useful for removing gelatinized starch from apple-pectin solutions.

The diastases of plant origin (from malt, *A. oryzae*, leaves, etc.) have a lower pH optimum range (a more acid reaction) than do those of animal origin. That for malt diastase is approximately 4.4 to 5.2 and for that from the pancreas it is pH 6.8. The diastase of the potato also has a high pH optimum, *viz.*, about pH 6.7.

The diastase of malt is considered by many to consist of two enzymes, *viz.*, "amylase" which liquefies starch and converts it to dextrin; and "dextrinase," which converts the dextrin to maltose. The word amylase also is commonly used interchangeably with diastase to denote any starch-hydrolyzing enzyme.

The rate of hydrolysis of starch is followed qualitatively by the iodine color reaction and quantitatively by measuring polarimetrically or chemically the rate of formation of sugars or by means of a viscosimeter measuring the decrease in the viscosity of gelatinized starch solutions.

The optimal temperature range for malt diastase is approximately 54 to 56°C.; for that of animal origin about 38 to 40°C. That of *A. oryzae* is nearer that of diastase of animal origin than of malt diastase.

Malt diastase is of great industrial importance since malt is used for converting the starch of various cereals, such as corn, rice, rye, and barley, to maltose in preparing beer, industrial alcohol, whisky, malt vinegar, distilled malt vinegar, and compressed yeast. Enormous quantities of barley are used for manufacture of malt. For this purpose the barley is first soaked (steeped) in water, drained, allowed to sprout under controlled humidity and temperature in slowly revolving steel drums or on a concrete floor, dried, and ground. For some purposes drying is omitted, the green, undried malt being used directly, as in the preparation of compressed yeast. The starchy substance to be hydrolyzed is usually gelatinized by heating with water. The saccharification by the malt is conducted at about 50 to 55°C., if a high yield of maltose and low yield of dextrin is desired, and at higher temperatures—*e.g.* for beer making—if considerable dextrin is desired, since the higher the temperature the higher is the ratio of dextrin to maltose.

Mold diastase is generally applied at lower temperatures than is malt diastase, as it is rather active at 38 to 40°C. It is useful for hydrolyzing the starch present in pectin-containing extracts of apples. In the making of saké, an alcoholic beverage of Japan and China, cooked rice is heavily seeded with *A. oryzae* spores. Growth of mold accompanied

by that of yeast ensures the starch is converted to sugar by the mold and the sugar to alcohol by yeast as the saccharification proceeds. Another mold, Amylomyces β (a Mucor), is used industrially to hydrolyze gelatinized starch solutions for subsequent fermentation by yeast and distillation for industrial alcohol or distilled beverages.

Pectic Enzymes.—Pectic substances of fruits and vegetables, according to present views, are attacked by three enzymes.

Protopectin, the binding substance of the middle lamella is hydrolyzed by an enzyme, protopectinase, occurring in plant tissues and in parasitic fungi. When it is dissolved by enzyme action, the cells are separated and the tissue softened. Its function in parasitic fungi is to enable the mycelium to penetrate the tissues. Probably the softening of pears, persimmons, apples, and other fruits during ripening involves conversion of some of the protopectin to pectin by enzyme action.

Pectase causes pectin solutions, in the presence of calcium salts, to form a gel of calcium pectate. It usually can be demonstrated by grinding citrus fruit peel very finely, pressing without heating, and allowing the juice to stand several hours. Apple juice occasionally exhibits this phenomenon. Clover, alfalfa, potatoes, and carrots contain active pectases. Evidently pectic acid and methyl alcohol are liberated by the hydrolysis.

Pectinase hydrolyzes pectin to its end products, *viz.*, arabinose, galactose, galacturonic acid, and probably methanol. The jellying power of the pectin is destroyed. The enzyme is secreted abundantly by certain microorganisms, notably *Bacillus carotovorus*, some Penicillium species, flax-retting bacteria, *Rhizopus tritici*, and some Fusarium species. Pitman in this laboratory found that wine yeast exerted no hydrolytic effect on pectin and that, therefore, in preparing pectin concentrates from fruits, the pectin extract made by boiling and pressing the fruit could be fermented with yeast to remove sugars without injury to the jellying power of the extract.

Cellulase.—Certain bacteria and fungi are capable of hydrolyzing cellulose (wood fiber) to water-soluble products and these in turn to simpler products, such as methane, carbon dioxide, alcohols, and organic acids. Bacterial decomposition of cellulosic waste materials has been used to generate gases for use for power and heat. However, the enzymes of the cellulose-splitting organisms have not been extensively studied. Waksman and Davison state that *Aspergillus cellulosae* (probably identical with *A. fumigatus*) can be used as a source of cellulase preparation, by growing it in the presence of filter paper as a source of cellulose and filtering through a Berkefeld filter. The filtrate contains the cellulase.

Cytases.—These enzymes are abundant in barley malt and other sprouted cereals. They hydrolyze hemicelluloses, which resemble

cellulose but which are more easily hydrolyzed. The products are glucose, mannose, galactose, and pentose sugars. Cytase is of importance during the mashing process of brewery and distillery operations, because it attacks the hemicelluloses of the starchy cereals, facilitating the action of the diastase of the malt upon the starch.

Emulsin.—There are probably a number of emulsins or emulsin-like enzymes all characterized by the ability to hydrolyze β-glucosides. As encountered in nature or in enzyme concentrates "emulsin" consists of several enzymes. It occurs abundantly in sweet as well as in bitter almonds and in the kernels of prune, peach, and apricot pits. It is also encountered in the leaves, stems, and roots of various plants, particularly those of the peach.

It is used industrially in preparing bitter almond oil (benzaldehyde) from bitter almonds and from apricot, cherry, and peach kernels. It is very useful in research on the naturally occurring glucosides, since it hydrolyzes them into a sugar and the compound with which the sugar is united.

It is easily prepared from sweet almonds by grinding, extracting with ether to remove the oil, extracting with dilute N/10 ammonium hydroxide to dissolve the enzyme, acidifying with acetic acid, fractionally precipitating with alcohol, and drying at room temperature.

Almond emulsin preparations contain several enzymes. One of these hydrolyzes amygdalin, the bitter glucoside of almonds and of apricot kernels, to one molecule of glucose and one of prunasin, a glucoside containing hydrocyanic acid. Prunase, another enzyme, then hydrolyzes prunasin to glucose and benzoic oxynitril (or benzaldehyde cyanhydrin), which is a compound of a benzaldehyde and hydrocyanic acid, HCN. A third enzyme, oxynitrilase, hydrolyzes the benzoic oxynitril to benzaldehyde ($C_6H_5CH{:}O$) and to hydrocyanic acid. Benzaldehyde imparts the characteristic odor and flavor to "wild cherry" flavor and similar preparations. It is a common ingredient of many essences and flavoring preparations. Hydrocyanic acid is extremely poisonous and must be removed by the treatment indicated in Chap. XXVII.

Emulsin is most active at 45 to 50°C. and at a reaction near neutrality. The course of the reaction may be followed polarimetrically, since the glucose formed is dextrorotatory, or by increase in reducing power on Fehling solution.

Tannase.—Certain molds, when grown on tannin solution, secrete a specific esterase capable of hydrolyzing depside tannins into phenol carboxylic acids and other compounds. Gallotannin, a glucoside, is hydrolyzed by certain molds to gallic acid and glucose (supposedly by the tannase). The enzyme has been useful in studying the constitution of tannins but is at present of no industrial utility. Probably tannases are concerned also in the ripening of fruits.

Lipases.—The lipases constitute an important and interesting group of esterases characterized by their ability to split fats and oils into glycerin and free fatty acids. They account for the increase in free fatty acid in stored copra (dried coconut meats), cottonseed, olives, and other oil-bearing materials. They are involved in the rancidification of butter and in the digestion of fats and oils in the body. Naturally, the hydrolysis of oils and fats requires the presence of water. In addition to the oils and fats the lipases attack other esters.

Sprouted castor beans are a common source of plant lipase for research use. This lipase is insoluble in water and is purified by removal of water-soluble materials and by centrifuging in contact with the castor oil; the enzyme remains with the oil.

Its presence can be demonstrated in olive tissue, particularly in the kernels, by allowing a mixture of the ground tissue and oil to stand in the presence of moisture and an antiseptic such as sodium benzoate. Increase in titratable free fatty acid is an indication of the presence of lipase. Waldschmidt-Leitz gives specific directions for measuring lipase activity.

It is present in the liver, the pancreas, and digestive fluids of the body.

In the preparation of some vegetable oils, *e.g.*, copra, heating the raw material probably inactivates the enzyme. In preparing olive oil, however, the enzyme may accompany the crude oil and in the presence of moisture will cause fairly rapid increase in free fatty acid. Consequently it is highly desirable to filter the new oil and to remove all accompanying juice or water before storing the oil.

Lipase of the human stomach has an acid optimum, *viz.*, a pH range of pH 4 to 5; whereas pancreas lipase and liver lipase prefer slight alkalinity. Castor-bean lipase has a pH optimum of about 4.7 to 5.0, a mildly acid range.

Chlorophyllase.—It was found by Willstätter and Stoll that there exists in leaves an enzyme, chlorophyllase, which hydrolyzes chlorophyll into the alcohol, phytol, and a chlorophyllin. In the presence of alcohol the latter forms an ethyl ester which is crystallizable. The enzyme is active in the presence of moderate concentrations of alcohol or acetone. It has been suggested that it may be active in spinach blanched at 160°F.; and its hydrolytic action on chlorophyll may account for the greater stability of the color in spinach so blanched. However, this question requires further study.

Proteases of Fruits and Vegetables.—The protein-splitting enzymes of animal tissues, such as pepsin and trypsin, have been studied much more extensively than those of plant tissues. Consequently plant proteases have not been so well differentiated as those of animal origin.

In the digestion of foods by animals, pepsin of the stomach hydrolyzes proteins to peptones (polypeptides) at a strongly acid reaction (about pH 1.5). Trypsin secreted by the pancreas then acts in the intestinal tract on the polypeptides, hydrolyzing them to amino acids and peptides; trypsin of the intestinal tract hydrolyzes peptides into the ultimate amino acids.

Proteases of Grains.—In the preparation of wort (saccharified barley malt solution) proteolytic enzymes are of great importance, since they partially hydrolyze the insoluble cereal proteins, converting them into soluble products useful as yeast food. In mashing (saccharification) the suspension of finely ground malt and water is maintained at a temperature of about 50°C. for a considerable period, usually 1 hr. or longer to permit proteolysis by the naturally occurring enzymes. These enzymes are favored by an acid reaction, attained by its development by thermophilic lactic acid bacteria. In the preparation of wort for growth of compressed yeast the proteolytic period is prolonged to several hours in order to obtain as complete breakdown as possible of the proteins to amino acids and peptones, thereby providing a suitable medium for maximum yield of yeast.

Papain.—In the milky juice of the papaya (*Carica papaya*) of the tropics is a very active protease, papain. Its activity is increased by hydrocyanic acid or hydrogen sulfide. Proteins and peptones are hydrolyzed while dipeptides are not attacked; therefore, it resembles trypsin rather than erepsin. Its pH optimum for gelatin is 5.0 and for peptone from albumin 5.0 to 5.2; these values being the isolectric points of the two substrates.

Papain and the papaya fruit have been used as an "aid to digestion" by food faddists and others; although it is doubtful whether the enzyme is of great value in that direction.

In preparing the purified enzyme the latex (milky juice) is allowed to harden and dry. It is then ground and extracted with water; the enzyme is precipitated by addition of 10 volumes of alcohol, redissolved in water, reprecipitated with alcohol, and dried *in vacuo*.

Bromelin.—Pineapple contains a proteolytic enzyme, bromelin, that acts not only upon proteins in solution but also upon the skin of the hands of cannery workmen. Experiments in this laboratory show that pineapple juice preserved by freezing storage retains its bromelin activity. The enzyme is rather rapidly destroyed, however, by pasteurization at 65°C. or above. Juice pasteurized at 60°C. (140°F.) a short time retained a considerable proportion of its bromelin activity.

The activity of bromelin, like that of papain, is enhanced by the presence of hydrocyanic acid or hydrogen sulfide.

Other Plant Proteases.—It has been found that pumpkin tissue contains a strong, proteolytic enzyme. It differs from bromelin and papain in that it is inhibited rather than activated by hydrocyanic acid and hydrogen sulfide and by the fact that it has an optimum pH value for gelatin hydrolysis at slight alkalinity rather than at pH 5.0.

The milky juice of unripe figs contains a powerful, proteolytic enzyme that appears to have received much less study than that of the papaya and pineapple. Those who are familiar with the fresh fruit are well acquainted with its action on the mucous membrane of the tongue and mouth or on the skin beneath the fingernails.

When moist yeast is allowed to stand in the presence of a mild antiseptic, it liquefies through self-digestion by its own proteolytic and other enzymes. It has been demonstrated that there are present in the yeast juice from autolysis a peptic enzyme, a tryptic enzyme, and an ereptase. The first acts on proteins only, the second on polypeptides and the third on dipeptides, just as pepsin of the stomach acts on proteins, trypsin of the intestinal tract on polypeptides and erepsin of the intestinal tract on dipeptides.

Fungi also secrete proteolytic enzymes which are found in certain commercial mold-enzyme preparations. In the manufacture of certain soybean products such as soybean sauce so generally used in cooking by the Japanese and Chinese, proteolytic enzymes of certain molds used in its manufacture are of very great importance in that they hydrolyze the soybean proteins to soluble peptones and amino acids.

Unpublished data of Osaki, a former graduate student in this laboratory, indicate that most fruits contain proteolytic enzymes in sufficient quantity to be demonstrated by their action on dilute heat-coagulated suspensions of egg albumen.

Zymase of Yeast.—Zymase is a complex of several enzymes which, acting in conjunction, are responsible for the transformation by yeast of certain hexose sugars into alcohol and carbon dioxide. The classic work of Buchner, reported in 1897, was the first demonstration of cell-free fermentation and the forerunner of much of our recent and modern research of enzyme chemistry and behavior. He ground yeast in a mortar with sand and diatomaceous earth and then subjected it to very high pressure. He secured a "yeast juice" which was then filtered. It slowly transformed sugars into carbon dioxide and alcohol, although there were no living yeast cells present.

If yeast is treated with acetone, the cells are killed but the zymase remains active. Another method of preparing zymase solution is to allow the air dry yeast to autolyze (undergo self-digestion) in water in the presence of a mild antiseptic. The filtrate contains zymase.

It was reported by Harden and Young in 1904 that zymase becomes more active on the addition of boiled yeast juice. It loses its activity on ultrafiltration and dialysis. In other words zymase requires an activator, cozymase, which is heat stable and of relatively low molecular weight. It is a phosphorus- and nitrogen-containing compound and is probably a nucleotide. An extract of muscular tissue will also activate zymase. The cozymase-free inactive enzyme is known as apozymase.

Harden and Young showed that a combination of phosphoric acid and hexose occurs in yeast juice. The addition of phosphate to yeast juice increases its activity. It is probable that the hexose phosphate (phosphoric acid-sugar compound) is an intermediate product in alcoholic fermentation. Four hexosephosphate compounds have been isolated, but it appears that the hexosediphosphate is the one most concerned in alcoholic fermentation. The enzyme responsible for the formation of hexosephosphates is known as phosphatase and is one of the enzymes of the zymase complex. Recently yeast phosphate has been used by University of Nevada chemists to convert soluble phosphate into a hexosephosphate for a fertilizer. In the free form, phosphates are rapidly converted into insoluble form in the soil and hence do not penetrate deeply and, if insoluble, are not readily assimilated by plants. The hexosephosphate does not form insoluble phosphates and, therefore, is carried downward in solution into the soil to a considerable depth. The procedure, however, is still in the experimental stage. If successful, it might provide an outlet for considerable quantities of agricultural carbohydrate wastes.

The next stage in alcoholic fermentation is, according to the Neuberg theory, formation of a compound of three carbon atoms, *viz.*, methyl glyoxal, CH_3COCHO. This compound undergoes transformation into pyruvic acid, $CH_3COCOOH$, part of which in turn is converted by the enzyme carboxylase into CO_2 and CH_3CHO (acetaldehyde). Acetaldehyde and methyl glyoxal undergo a Cannizarro reaction to form alcohol and pyruvic acid. The cycle is continuous. The Neuberg and other theories of alcoholic fermentation are discussed more fully in Chap. XXX.

The enzyme responsible for conversion of hexose sugars into lactic acid is also sometimes known as a zymase.

General Properties of Oxidizing Enzymes of Plants.—Several kinds of oxidizing enzymes are found in plant tissues, the character of the enzymes and substrates varying to a considerable extent with the plant and character of the tissue. Thus the oxidizing enzymes of fungi and other microorganisms differ from those of the apricot or apple.

Insofar as food-processing operations are concerned, oxidizing enzymes of fruits and vegetables are of interest principally for the undesirable changes induced by them. Such changes are the darkening of fruits during drying or in the interval between peeling and canning; development of undesirable oxidative changes in flavor and odor in dried

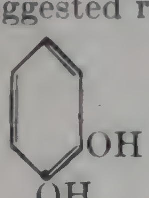
fruits and in frozen pack-fruits and vegetables; and destruction of vitamin C by oxidase.

Several theories of biological oxidation have been advanced. One of the earliest is that of Bach and Chodat who postulated that peroxides are formed as a necessary step in the oxidation process. These possess a much higher oxidizing activity than atmospheric oxygen. The substance that forms the intermediate peroxide was termed A, or the autooxidizable substance. The peroxide could in turn oxidize additional A or could react upon a second substance, B. They also believed that an enzyme hastened formation of the peroxide. The series of reactions suggested were:

$$\begin{gathered} A + O_2 \rightarrow AO_2 \\ AO_2 + B \rightarrow AO + BO \\ AO + B \rightarrow BO + A \\ A + O_2 \rightarrow AO_2. \end{gathered}$$

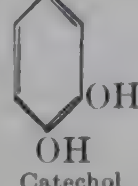
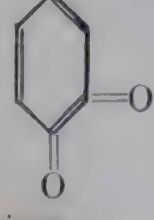
By some, the autooxidizable substance which forms the intermediate peroxide is termed an "oxygenase"; by others, this term is applied to the enzyme which hastens formation of the organic peroxide. It is now well established that AO_2, the peroxide, does not ordinarily react directly upon B, the substrate, but requires catalysis of the reaction by the enzyme peroxidase. Peroxidase cannot utilize free oxygen, but only that in the form of hydrogen peroxide or organic peroxide.

One of the most plausible theories of oxidation in plant tissues is that of Onslow. She states that many plants contain compounds possessing an orthodihydroxy grouping characteristic of catechol, these substances being autooxidizable and capable of forming quinone-like compounds and peroxides. The oxidation of these substances is catalyzed by an enzyme, oxygenase, present in the tissues. Hydrogen peroxide may be formed also. Peroxidase, an enzyme, catalyzes the reaction between the peroxides and certain oxidizable phenolic substances. Suggested reactions are:

1.  + O_2 + oxygenase → catechol peroxide

Catechol

2. Catechol peroxide + $H_2O \rightarrow H_2O_2$ + some oxidized product of catechol

3. H_2O_2 + peroxidase +  →  $+ 2H_2O$

Hydrogen peroxide; Catechol; Catechol quinone; water

Similar reactions would occur with other orthodihydroxy compounds, such as caffeic acid, protocatechuic acid, homocatechol, etc. The orthoquinone has been isolated and identified by Onslow. She believed that it is probably the principal intermediate compound involved in causing oxidations of other substances in plant tissues.

The oxygenase has not been prepared free of peroxidase, although by suitable fractional precipitation Onslow claimed to have prepared peroxidase free of oxygenase. Peroxidase and oxygenase in mixture, but free of the autooxidizable orthodihydroxy substances, can be prepared by grinding fresh fruit or vegetable tissue in a mortar in 95 per cent ethyl alcohol which dissolves the orthodihydroxy compounds and precipitates the enzymes. The enzymes can be recovered from the pulp by dissolving in dilute sodium bicarbonate solution. The latter is then neutralized with dilute organic acid to any desired pH value.

The Wieland theory of general biological oxidation holds that the process is one of dehydrogenation. The first step is activation of certain hydrogen atoms of the substrate. The activated hydrogen is then removed by some hydrogen acceptor such as oxygen which may form hydrogen peroxide. *In vitro* methylene blue can act as a hydrogen acceptor. For example in the presence of a suitable oxidase of the Wieland type, *viz.*, a dehydrogenase, and methylene blue, alcohol is oxidized to acetic acid. The methylene blue may be indicated by the symbol MB. The reactions postulated then are:

1. $\underset{\text{Alcohol}}{CH_3CH_2OH} + MB + \text{dehydrogenase} \rightarrow \underset{\text{Acetaldehyde}}{CH_3CH{:}O} + \underset{\text{Reduced methylene blue}}{MBH_2}$
2. $\underset{\text{Acetaldehyde}}{CH_3CH{:}O} + \underset{\text{Acetaldehyde}}{CH_3CH{:}O} + H_2O \rightarrow \underset{\text{Acetic acid}}{CH_3COOH} + \underset{\text{Alcohol}}{CH_3CH_2OH}$

In the presence of oxygen and absence of methylene blue the reactions might be:

1. $CH_3CH_2OH + O_2 \rightarrow CH_3CH{:}O + H_2O_2$
2. $CH_3CH_2OH + H_2O_2 \rightarrow CH_3CH{:}O + H_2O$
3. $CH_3CH{:}O + CH_3CH{:}O + H_2O \rightarrow CH_3CO_2H + CH_3CH_2OH$

The above reactions have been somewhat simplified from those given by Wieland.

Warburg's theory is at variance with that of Wieland in that he believed that all biological oxidations required iron of special properties. The first step is a reaction between iron of the tissues with oxygen of the air. The second step is transfer of the oxygen to the substrate with corresponding reduction of the iron complex. The reaction is catalyzed by oxidase. Prussic acid, HCN, inhibits the reaction.

There is evidence to support all of these theories, and it is probable that several types of oxidizing systems exist in plant and animal tissues,

viz., those in which the phenolase type of oxidizing system of Onslow prevails, those in which the dehydrogenase system of Wieland is concerned, and those in which the iron-containing, prussic acid-sensitive enzyme of Warburg is operative. In fruits, oxidases of the Onslow type are most in evidence, whereas for animal tissues dehydrogenases are abundant.

Recently, as mentioned in Chap. XXXII, Warburg and associates as well as others have isolated the so-called, "yellow ferment of Warburg," an oxidizing enzyme, part of which is lactoflavine of the vitamin G complex. Lactoflavine is diffusible and relatively simple in structure; the remainder of the enzyme complex is a protein of high molecular weight. Boiling destroys the enzyme but not vitamin G.

It is likely that glutathione, a sulfur containing compound, and present in plant as well as animal tissues, is involved in certain oxidations and reductions since it may act as an oxygen or hydrogen carrier, owing to its susceptibility to oxidation and reduction. Lactoflavine of the vitamin G complex, free of its colloidal carrier, is said to possess some catalytic activity in oxidation and reduction. See also cytochrome, page 779.

Oxidase of Fruits.—Onslow's theory explains very well the browning of cut fruits, fruit juices, and some vegetables. The presence of ortho-dihydroxy compounds in many fruits can be demonstrated readily by grinding the fruit into several volumes of 95 per cent alcohol; pressing; filtering; removing the alcohol by distillation; and testing the aqueous residue with a few drops of ferric chloride followed by addition of excess sodium bicarbonate. A green color develops with ferric chloride, and this color is turned to purple by the sodium bicarbonate. The presence of peroxidase is proved by addition of gum guaiac solution or dilute benzidine solution and dilute hydrogen peroxide to an aqueous extract of the previously alcohol-extracted tissue.

In most fruits there is, according to Onslow, a complete oxidase system, *viz.*, an autooxidizable substance such as a catechol compound, an oxygenase, and a peroxidase. Hence, when dilute benzidine is added without hydrogen peroxide to fresh apple juice or fresh peach juice a pink to purplish color slowly develops. If the autooxidizable substance and oxygenase were absent, there would be no change in color of the benzidine because oxidation would not occur.

If fruit juice is allowed to stand for several hours, often the benzidine reaction becomes negative; but it again becomes positive if hydrogen peroxide or if a trace of catechol is added. This observation indicates that in the first instance the autooxidizable substance and intermediate peroxide have been completely utilized, but that the oxygenase (if such exists) and the peroxidase are still active.

The well-known inhibiting action of sulfur dioxide on the darkening of fruit products, it is believed from the research of Overholser and Cruess, is due to its union with the oxygenase or organic peroxide, rather than with the peroxidase (see reference list).

The peroxidases of fruits are inhibited by chlorides, oxalate, and by low pH values (high acidities). Darkening of peeled peaches, apples, and pears is retarded by wetting them with or by immersing them in dilute brine or dilute organic acid, such as citric or malic, until canned.

In the natural fruit tissues the peroxidase is most abundant along the fibrovascular bundles, as can be readily demonstrated by applying dilute hydrogen peroxide and benzidine solutions to the cut fruit surface.

At the normal pH range, 3.8 to 4.5 existing in fruits, purified fruit oxidase is destroyed at 65 to 75°C. in 2 min. Therefore, if oxidation of frozen-pack juices is to be prevented, the juices should be flash pasteurized for a time and at a temperature sufficient to destroy the oxidative enzymes. While the peroxidase of fruits can be destroyed readily by heating and the fruit then dried in the usual manner, the dried fruit soon darkens because of autooxidation of certain substances, probably of orthodihydroxy compounds. Apparently sulfur dioxide is necessary (insofar as present knowledge indicates) to prevent such darkening of dried fruits.

In canned fruits and bottled juices darkening by oxidase activity is not a factor, since air is excluded. Darkening of jams and syrups is evidently not enzymic and is probably not oxidative, since it can occur in the complete absence of oxygen as well as in its presence.

Vitamin C Oxidase.—If freshly expressed tomato and apple juices are allowed to stand a few hours in the presence of air, they completely lose their vitamin C potency. If, however, the fruit is heated to boiling before pressing, the rapid vitamin C destruction does not occur. Evidently, the destruction is oxidative and caused by a heat-labile enzyme. Szent-Györgyi found that cabbage contains a similar enzyme. Hubbard squash also contains a vitamin C destroying oxidase. Probably, similar enzymes occur in other fruits and vegetables, although vitamin C is rather stable in citrus juices, indicating absence or very low content of the oxidase. Considerable research has been conducted by the New York Agriculture Experiment Station on this enzyme.

Vitamin C oxidase is also known as "ascorbase" and as ascorbic acid oxidase. Since vitamin C is now easily determined by titration methods, the course of destruction of the vitamin ascorbase can be followed accurately.

Tyrosinase.—Potatoes contain an enzyme that catalyzes the oxidation of tyrosine (a phenolic amino acid) to a dark melanin-like substance of complex nature. Tyrosine is not oxidized by fruit peroxidases.

Cytochrome.—In many plant and animal tissues exists a pigment known as cytochrome, which has been proved by Keilin and others to be of importance in biological oxidations and reductions. Cytochrome is a mixture of three hemochromogen-like substances *a*, *b*, and *c*. Cytochrome is oxidized by oxygen, the reaction being catalyzed by indophenol oxidase. In the living cell the oxidized cytochrome is reduced by dehydrogenase. The changes can be followed in yeast by means of a spectroscope. The cytochrome acts as an oxygen carrier, in conjunction with an oxidase and a dehydrogenase.

Catalase.—Although it is not an oxidizing enzyme, catalase is closely related to oxidizing enzymes. It decomposes hydrogen peroxide into molecular oxygen and water:

$$2H_2O_2 + \text{catalase} \rightarrow O_2 + 2H_2O$$

Catalase occurs in most animal and plant tissues, where its function appears to be to prevent toxic accumulation of hydrogen peroxide formed in dehydrogenating reactions. Some bacteria are devoid of catalase and under suitable cultural conditions hydrogen peroxide accumulates in the culture.

Catalase is very abundant in almond kernels, in the saliva of the mouth, in the blood, and in the liver. It also is abundant in green fruits and in potato tubers. Its presence is quickly demonstrated by applying dilute hydrogen peroxide solution to the cut surface of fruits or by adding it to the fresh juice. The reaction may be followed quantitatively by measuring the rate of evolution of oxygen from hydrogen peroxide.

Sumner and Dounce have prepared crystalline catalase. It is yellow in dilute solution and brown in concentrated. Its activity is destroyed by heat. It gives tests for protein and hemochromogen and contains 0.10 per cent of iron.

The effectiveness of blanching of peas for frozen pack is judged by Diehl by the presence or absence of catalase in the blanched product; if absent, blanching has been considered sufficient. The work of Joslyn and Marsh indicates that a considerably longer period of blanching is required than that barely necessary to destroy catalase in order that enzymic deterioration may not occur after blanching.

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